Journal of Architectural Research and Development, 2022, Volume 6, Issue 5
http://ojs.bbwpublisher.com/index.php/JARD
ISSN Online: 2208-3537
ISSN Print: 2208-3529

Comparison of Illuminance in Different Environments: A Case Study on Subway Stations

Tao Wang*, Jie Su

China Railway Siyuan Survey and Design Group Co., Ltd, Wuhan 430063, Hubei Province, China

****Corresponding author:*** Tao Wang, wangtaozhongtie4@aliyun.com

Abstract: With urbanization and the rapid development of social economy, China's rail transit industry has developed rapidly in recent years. In order to alleviate the pressure of road network, subways provide convenience as they are fast and space-saving. Subway stations are major energy consumers of urban power grid due to their large traffic volume and long operation time. On the premise of ensuring operation safety, reducing the energy consumption of subway helps in energy conservation and emission reduction as proposed in the 13th Five-Year Plan. According to the statistics of the energy-saving evaluation report of rail transit engineering, the lighting system accounts for 20%–30% of the total power consumption of the subway station. Due to the single lighting control mode of the lighting system in the subway station, the actual station illumination cannot be reported and adjusted in time, resulting in the waste of lighting energy and high power consumption of the system. Through in-depth research on the intelligent lighting system of subway station, this paper improves the system control, and finally summarizes the optimization scheme of subway station lighting design which can effectively save the power consumption of lighting system. The main contents of this paper are as follows: The research results of this paper can provide effective measures for energy saving of electric lighting in subway stations and reduce electric energy consumption; on the other hand, as an integral part of building lighting energy-saving system, it also has certain guiding significance for the research of building lighting energy-saving.

Keywords: Subway illumination; Architectural lighting; Indoor thermal environment

Online publication: September 27, 2022

1. Introduction

The comprehensive energy consumption level of rail transit is lower than other forms of transportation with similar capacity. However, due to the large traffic volume and long operation duration, the total power consumption of rail transit is still high. Therefore, the power consumption of rail transit still has the potential of energy saving to a certain extent. In recent years, the subway construction scale and planned routes have been further expanded with growing investments and increasing construction speed. Facing such a huge urban rail transit network, subway has become the main electrical consumption equipment of the city. In order to respond to the 13th Five-Year Plan for building energy conservation and green building development issued by the Ministry of housing and urban rural development and implement the objective requirements of national energy construction and production [1–3], the goal of energy conservation and emission reduction should be reflected in the whole process of subway design. Therefore, the construction of rail transit should be people-oriented and be fast, convenient, and punctual. At the same time, according to the basic principle of energy conservation, the management of energy conservation and emission reduction of rail transit should be improved, the cost of energy use should be reduced, the utilization efficiency of energy should be increased, and the pollution of resources and environment should be reduced [4–6].

It can be seen from **Table 1** that the lighting system occupies 15% – 35% of the energy consumption of the whole subway station. According to the 2016 urban rail transit report, there were at least 260 subway lines under construction in China [1]. Although the scale of subway stations and the lighting scale are small, considering the large number of subway lines, their scale and number far exceed that of large buildings. In view of such high lighting energy consumption, reduction of energy consumption of the lighting system, improvement of the utilization rate of lamps, proper utilization of existing resources on the premise of meeting the working lighting of subway stations has long-term significance for the development of urban rail transit in the future [7–9].

Table 1. Total electricity consumption forecast for the entire station of the Metro Line 2

		Initial stage			The near future			Future		
Name of lighting load		**Power (Kw)**	**Average daily power consumption time (h)**	**Total annual electricity consumption (10^4 kWh/year)**	**Power (Kw)**	**Average time of power consumption (h)**	**Total annual electricity consumption (10^4kWh/year)**	**Power (Kw)**	**Average time of daily power consumption (h)**	**Total annual electricity consumption (10^4 kWh/year)**
Emergency light		8	24	7	8	24	7	8	24	7
Equipment area lighting		40	18	26.3	40	18	26.3	45	18	29.6
Public area lighting	*Electricity saved*	20	18	13.1	20	12	8.8	20	12	8.8
	Work	20	12	23.4	54	12	23.5	62	12	27
Other lighting loads such as advertisers		53	12	23.4	54	12	23.5	62	12	27
Total		-	-	78.6	-	-	78.7	-	-	85.5

2. Literature review

2.1. Foreign Research Status

Subway is an important mode of transport is many countries. Since the official construction of the world's first subway in London, the British capital, in 1863, nearly 300 subway lines have been constructed in more than 80 cities around the world, with a total length of more than 5100 km [10]. The research on lighting design abroad is more in-depth, and various countries have formulated corresponding lighting design standards of underground railways.

Germany, Singapore and Japan attach great importance to the design of subway lighting, emphasize comfort, use lighting to enhance the appearance of space, and make full use of the hierarchical design of lighting in lighting engineering [11,12]. OSRAM lighting company provided lighting for 162 New Delhi metros in India, installed parallel strip light panels on their roofs, and used the lighting control system to adjust and control the lamps within the predetermined range, which not only provided high-quality visible light, but also arranged the ceiling of the station in an artistic way, with excellent ornamental performance [13.14].

2.2. Domestic research status

In the early stage of subway construction and development, according to the specific practice of subway construction, China has designed the national standards: "Subway Lighting Standard" (GB/T 16275-1996) and "LED Lighting Design Standard for Subways Stations" (DB44/T 1620-2015), which stipulate the lighting degree, color temperature and lighting density of subway platforms [15]. At the same time, passageways, waiting halls, transitional passageways and other functional spaces were also given attention. Due to the lack of computer technology, the unified lighting layout causes no sense of hierarchy in the lighting and are unable to act as guides. The designed lighting environment is difficult to make passengers feel comfortable [16]. In the next 10 years, China's rail transit construction will enter an unprecedented period of prosperity. With the continuous improvement and perfection of lighting system design, intelligent lighting system will become a new direction in the field of lighting control [17,18].

3. Methodology (Data collection)

3.1. Experiment set-up

The research object of this project is Xi'an Lijiacun subway station. The research results of this paper can provide effective measures for energy saving of electric lighting in subway stations and reduce electric energy consumption. The performance of the instruments used are shown in **Table 2**.

Table 2. The performance of the instruments

Instrument	Measuring range	Measurement accuracy	Equipment size	Work environment
Noise detector (noise0501)	30db–120db	±0.5db	8*5*12cm	Air temperature: -40％~+60％ Relative humidity: 25％~90％ Static pressure: 65kpa~106kpa
Wind speed detector (wind0501)	0.2m/s–10m/s	±0.02m/s	8*5*12cm	-10℃~+50℃
Black ball temperature/ Humidity detector/ Illuminance detector	Illumination: 0~65535lux Humidity: -40℃~+125℃ Black ball: -10℃~+85℃	Humidity: ±0.3℃，±2％RH Black ball: ± 0.5℃	12*8*6cm	

The parameters measured in the study includes: wind speed, noise, black ball temperature, humidity and illumination information of the subway station.

The wind speed and noise information were recorded once every minute; the collection interval of temperature, humidity and illumination information was once every 10 minutes. The collected information will be uploaded to the server of the equipment operator and stored. The stored information can be viewed and downloaded at any time.

The period of data collection was from July 15, 2021 to August 10, 2021. All equipment operated continuously for 24 hours during the testing period.

All equipment monitored were non-radioactive and were placed against the wall, with a total floor space of about 1.5 square meters. Therefore, the operation of the subway was be affected during the monitoring period.

4. Results

4.1. Illuminance

4.1.1. Underground is measured two-point illumination description

Table 3. A1, A2 point illumination description

	A1 point illumination（lx）	**A2 point illumination（lx）**
Mean	123	118.52
Median	121	136
Max	126	145
min	110	81

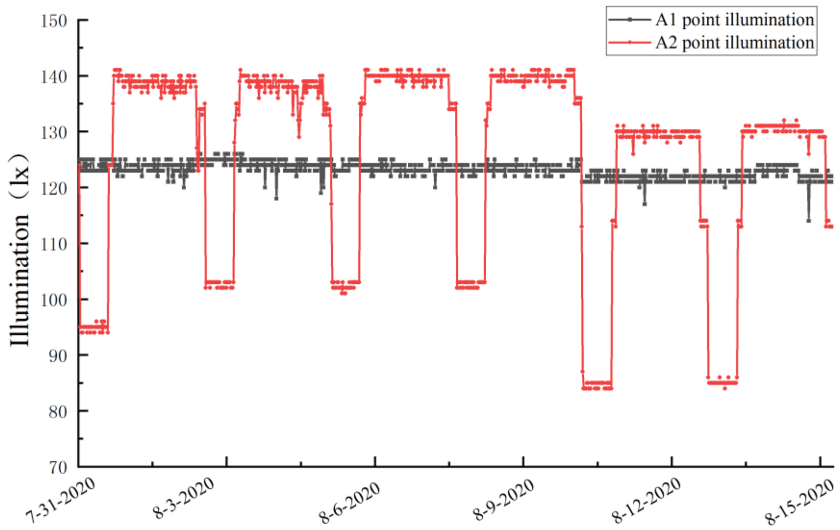

Figure 1. Scatter-point line chart of illuminance at each point on weekdays

(1) During the period of data collection, the illumination sensor is used to continuously collect the illuminance data on the two collection points A1 and A2 every 10 minutes, and the total data collected was 3744 copies (1872 copies of data for each collection point).

(2) As shown in **Figure 1**, it is the illumination change diagram of the two collection points. It can be seen from the figure that the illuminance value fluctuates up and down within 95(lx)-140(lx).

(3) As we can see from **Table 3** and **Figure 1**:

The peak value of the illuminance changes at point A1 is 142 (lx), which mainly occurs at 7:50 on August 9, 18:50-22:30 on August 9, and 9:20-13:10 on August 10. The illuminance changes at point A1 The valley value of 84(lx) mainly appeared on August 10th at 22:40-23:50;

A2 point illuminance change is relatively stable, there is not much fluctuation, it has been around 123lx. However, at 22:00 on August 14th the illuminance value was reduced to 110lx.

4.1.2. Compare with national standards

Underground space is one of the important public spaces in the city, and its sound, light and heat environments are crucial to residents' physical and mental health and ride comfort. At present, the domestic illumination standards for subway spaces are based on GB 50034-2018 “Architectural Lighting Design Standards”, GB 50016-2014 “Code for Fire Protection in Architectural Design”, GB/T16275-2008 Urban Rail Transit Lighting” whereas the designs are according to the relevant content of national standards such as 06DX008-1 “Electrical Lighting Energy Saving Design” [19]. The lighting power density value of the relevant space can used as a reference to better control the lighting energy consumption of the subway station, so as to guide the designer to in saving lighting energy while making a comfortable light environment.

5. Conclusion

Good lighting design and improving the design of the lighting control system in subway stations has gradually become an important part of modern subway stations. Because the current lighting and control technology in the existing subway station lighting system is relatively outdated, and there is a lack of consideration for passengers’ vision and energy saving, it is necessary to optimize the existing subway station lighting system.

With the continuous improvement of lighting system design, the application of lighting system in new urban subway stations will increase with more variety of systems. As for now, the lighting system only satisfies the comfort of the light environment, and is slightly lacking in the artistic expression of the light environment of the station. Relying on the characteristics of intelligent lighting single lamp dimming, various control modes, and the ability to monitor and control the status of each lamp, the future intelligent lighting control can achieve a variety of lighting effects, making the light environment of subway stations more beautiful and intelligent.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Deng Q, 2019, Research on the Development Trend of Urban Rail Transit Energy Saving Technology. Traffic World, 2019(Z1): 250–251.

[2] Zou H, 2014, Design and Implementation of Urban Smart Lighting System in Tongzhou District, Beijing, dissertation, Tianjin University.

[3] Yu X, 2007, Simulation and Research on Passenger Flow and Vehicle Flow in Urban Rail Transit, dissertation, Beijing Jiaotong University.

[4] Tan B, Liu J, 2017, Design of Distributed Intelligent Lighting Control System Based on IEC 61499. Modern Electronic Technology, 40(22): 182–186.

[5] Kim I-T, Jang I-H, Choi A-S, et al., 2015, Brightness Perception of White LED Lights with Different Correlated Color Temperatures. Indoor and Built Environment. 24(4): 500–513

[6] Hou X, Duan Z, Ma B, 2014, Research on Intelligent Control of Artificial Light Environment in Urban Subway Stations. Industrial Control Compute, 27(05): 79–80 + 83.

[7] Li C, 2012, Research on Thermal Environment Characteristics of Residential Areas Based on Planning Elements, dissertation, Anhui University of Architecture.

[8] Zhao W, 2016, Research on Optimal Design of Sound and Light Environment in Commercial Building Atrium, dissertation, Wuhan University.

[9] Yu W, 2018, Research on the Interactive Relationship Between the Spatial Structure of Villages in

Severe Cold Regions and the Traffic Sound Environment, dissertation, China University of Mining.
[10] Izadi T, Mehrabian MA, Ahmadi G, et al., 2021, Numerical Analysis of the Mirco-Particles Istribution Inside an Underground Subway System due to Train Piston Effect. J. Wind Eng. Ind. Aerod, 211: 104533.
[11] Shakya KM, Saad A, Aharonian A, 2020, Commuter Exposure to Particulate Matter at Underground Subway Stations in Philadelphia, Build. Environ. 186: 107322.
[12] Moreno T, Reche C, Minguillón MC, et al., 2017, The Effect of Ventilation Protocols on Airborne Particulate Matter in Subway Systems. Sci. Total Environ, 584-585: 1317–1323.
[13] Kim K-H, Ho DX, Jeon J-S, et al., 2012, A Noticeable Shift in Particulate Matter Levels After Platform Screen Door Installation in a Korean Subway Station, Asian J. Atmos. Enviro 49: 219–223.
[14] Chen T, Cao SJ, Wang J, et al., 2021, Influences of Optimized Air Curt at Subway Entrance to Reduce the Ingress of Outdoor Airborne Particles. Energ. Buildings, 244: 111028.
[15] Park S, Kim M, Kim M, et al., 2018, Predicting PM10 Concentration in Seoul Metropolitan Subway Stations Using Artificial Neural Network (ANN), J. Hazard. Mater. 341: 75–82.
[16] Lee S, Hwangbo S, Kim JT, et al., Gain Scheduling-Based Ventilation Control with Varying Periodic Indoor Air Quality (IAQ) Dynamics for Healthy IAQ and Energy Savings. Energ, Buildings 153: 275–286.
[17] Kim MJ, Sankara Rao B, Kang OY, et al., 2017, Monitoring and Prediction of Indoor Air Quality (IAQ) in Subway or Metro Systems Using Season Dependent Models, Energ, Buildings 46: 48–55.
[18] Wang J, Huang J, Feng Z, et al., 2021, Occupant-density-detection based energy effificient ventilation system: Prevention of infection transmission, Energ. Buildings 240: 110883.
[19] Peng J, Kimmig A, Wang J, et al., 2021, Dual-Stage Attention Based Long-Short-Term Memory Neural Networks for Energy Demand Prediction, Energ. Buildings 249: 111211.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.