Lighting environment analysis of Chengdu underground commercial spaces

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Abstract. In order to learn the current lighting environment of underground commercial space in Chengdu, we selected the Sino-Ocean Taikoo Li Chengdu, Tianfu Square Jinzhan Shopping Center and Diyi Avenue Underground Commercial Street as the research objects and using field test method to investigate the illuminance, lights colour temperature and the road surface luminance. Through contrast test data to analyse the lighting environment, this paper put forward the suggestions such as bring in natural light, adding commercial stores in channels and selecting colour temperature reasonably to enhance the lighting environment of underground shopping malls which only under artificial lighting conditions.

1. Introduction
With the continuous advancement of urbanization and the shortage of land resources, the spatial arrangement of infrastructure and various types of buildings has become increasingly difficult in conventional urban planning. The development of underground space has become one of the effective ways to alleviate resource pressure and comprehensively utilize urban land resource. The development and utilization of underground space can not only cure the 'urban disease' of resource shortage, but also promote the intensive development of the city to a large extent, accelerate the integration of urban center business and evolve to a higher form [1].

Underground commerce is one of the main forms of urban underground space development and utilization. In the 2019 China City Business Charm Rankings, Chengdu, ranking fourth in China, has risen by one in urban hub and lifestyle diversity, and even surpassed Shenzhen in the first line. Chengdu is the city with the highest talent attraction index in the new first-tier cities. Its regional center of business resources ranks third, and the number of food and beverage outlets, bars and clothing stores ranks first in China. Chengdu's business has broad prospects for development. And with the continuous acceleration of Chengdu subway construction, the subway-centered underground business will usher in a golden period of vigorous development. As an important part of underground business, lighting environment plays a vital role in the comfort of underground space. Illuminance, luminance and color temperature are the main parameters of lighting design and the main indicators for evaluating light
environment usually. Relevant literatures show that[2], in terms of color temperature, it is better to use a light source of 4000~8000K color temperature above the underground commercial passage to give people a refreshing and calm feeling; in the location close to the store, a light source of 2000~3000K color temperature should be used to set off Business atmosphere. In terms of luminance, the basic lighting illumination of small stores should be 300lx, and the basic illumination of supermarkets should be 500~750lx. Appropriate wall illumination can increase the luminance of the space and activate the indoor atmosphere [3].

This paper conducts on-site testing and investigation on the current lighting status of underground commercial space in Chengdu, in order to provide data support for lighting improvement and design of underground space in Chengdu.

2. Methods

2.1. sites
This paper selects three typical underground commercial spaces in Chengdu as research objects. They are Sino-Ocean Taikoo Li Chengdu, Tianfu Square Jinzhan Shopping Center and Diyi Avenue Underground Commercial Street. The main field test parameters are luminance and color temperature. In those test sites, Sino-Ocean Taikoo Li Chengdu is upscale shopping center, Jinzhan shopping center and Diyi Avenue are positioned as mass-market customers. The test object covers a comprehensive range and can be used as a representative of Chengdu underground commercial lighting environment.

2.2. Field measurement
The instrument used in this test is the luminance meter (Fig. 1). The test method is to test the color coordinates of the light by a luminance meter, according to the color temperature formula [4]:

\[ N = (x - 0.330)/(0.1858 - y) \]  

Where x, y are the color coordinates of any point on the isothermal temperature line.

The empirical formula for the color temperature value of the light sources is:

\[ \text{CCT} = 499N^3 + 3525N^2 + 6823.3N + 5520.22 \]  

Where A is the reciprocal of the slope of the equal color temperature line.

Convert the color coordinates to color temperature, and obtain the color temperature value of the test area.

![Illuminance meter and chroma meter](image)

Figure 1. Illuminance meter and chroma meter

3. Results

3.1. Sino-Ocean Taikoo Li test situation
We Investigated the illuminance, luminance and color temperature on floor B1 of the Sino-Ocean Taikoo Li Chengdu, which is the upscale commercial representation in Chengdu. The survey situations are in Figures 2 and 3. In the selection of light sources, Sino-Ocean Taikoo Li has a high degree of unity, all regions using the same point light sources. In the light sources’ arrangement, They are hidden to avoid direct to eyes. By actual measurement, the road luminance of Figure 2 is 35.9 cd/m², the illuminance is 230lx, the light source color temperature is 3066K, the road luminance of Figure 3 is 31.0 cd/m², the illuminance is 205lx and the light source color temperature is 2919K.
As for the underground passages, the channels with and without commercial stores were selected for comparison. The survey situations are shown in Figure 4 and Figure 5. By actual measurement, the luminance of passage with commerce is 62.6 cd/m² while passage without commerce is 10.6 cd/m². Similarly, the illuminance of passage with commerce is 236lx while passage without commerce is 107 lx. It can be seen that the channel's lighting parameters have a significant boost with store lighting on both sides.

Sino-Ocean Taikoo Li Chengdu bring in natural light into the underground space (as shown in Figure 6), making the channel's floor luminance reach 411 cd/m², the illuminance reach 720lx, which is much higher than the lighting parameters of other test areas.

3.2. Tianfu Square Jinzhan Shopping Centre test situation
The light sources type of the Jinzhan Shopping Centre is quite rich, including the point light sources shown in Figures 7 and 8, and the planar light sources as shown in Figure 9. Through actual measurement, the luminance of the light source of test area 1 (Figure.7) is 31800 cd/m², the road luminance is 22 cd/m², the color temperature of the light source is 4422 K, the illuminance is 245lx. The luminance of the light source of test area 2 (Fig. 8) is 36600 cd/m², the road luminance is 51.8 cd/m², the colour temperature is 3479K, and the illuminance is 223lx. Test area 3 (Fig. 9) uses planar illumination with the light source luminance of 937cd/m². The road luminance is 185cd/m², the colour temperature is 4022K and the illuminance is 613lx.
3.3. Lighting test of underground commercial street in Diyi Avenue

The light source luminance of test area 1 (Figure. 10) is 17200 cd/m², the ground luminance is 16.7 cd/m², the illuminance is 123lx, and the color temperature is 5763K. The light source luminance of test area 2 (Figure. 11) is 18400 cd/m², the ground luminance is 13.8 cd/m², the illuminance is 97lx and the color temperature is 3610K. Test area 3 (Figure. 12) is an underpass, located on the second-floor basement of Diyi Avenue, using linear illumination, the light source luminance is 7960 cd/m², the ground luminance is 4.61 cd/m², the illuminance is 23 lx and the color temperature is 5569K.

3.4. Summary of lighting test data

| Fig 2 | Fig 3 | Fig 4 | Fig 5 | Fig 6 | Fig 7 |
|-------|-------|-------|-------|-------|-------|
| Color temperature | 3066K | 2919K | 3013K | 3102K | 5700K | 4422K |
| Illuminance | 230lx | 205lx | 236lx | 107lx | 720lx | 245lx |
| Ground luminance | 35.9cd/m² | 31cd/m² | 62.6cd/m² | 10.6cd/m² | 411cd/m² | 22cd/m² |
| Fig 8 | Fig 9 | Fig 10 | Fig 11 | Fig 11 | Standard value |
| Color temperature | 3479K | 4022K | 5763K | 3610K | 5569K | 3300~5300K |
| Illuminance | 223lx | 613lx | 123lx | 97lx | 23lx | 200lx |
| Ground luminance | 51.8cd/m² | 185cd/m² | 16.7cd/m² | 13.8cd/m² | 4.61cd/m² | —— |

It can be seen from fig13(a) that the illuminance values of multiple measuring places in Sino-Ocean Taikoo Li Chengdu are higher than the national standard values. Only the passageway without commercial lighting is lower than the national standard, only 107lx, which reflects the important role of
the commercial lights in enhancing the illuminance of pedestrian walkways in underground shopping malls. In the area illuminated by nature light, the illuminance value is as high as 720lx, which not only provides a high-quality light-environment, but also saves energy and eco-friendly. Research on the light environment of subway stations has shown that passengers can feel psychologically stable in an underground space using either uniform illuminance or a stable lighting scheme, and the problem caused by the closed nature of the underground space can be solved by the introduction of natural light [5][6]. From the perspective of comfort, the wavelength distribution of nature light is more uniform than that of artificial light, the visual efficiency of human eyes is higher, and the color rendering and comfort are better.

It can be seen from fig13(a) that the illuminance values of all the measuring places in the Tianfu Square Fashion Shopping Center are higher than the national standards, and the place illuminated by planar lights are much higher than the other places in the illuminance value. In addition, we found that the planar light source has a great advantage in uniformity ratio of illuminance compared to the point source in the test.

In the Diyi Avenue(fig10~fig12), all measured points are lower than the national standard, the overall space is darker, giving people the more negative feeling. This situation should be avoided in lighting environment design.

From the point of color temperature(fig13(b)), Taikoo Li’s lights are unified. The color temperature of the lights are near 3000K, and the color temperature is slightly warmer than the national standard. Due to the large types of lights, the color temperature of Tianfu Square Fashion Shopping Center is between 3400K and 4200K, which is mussy, but all the values are within the recommended range of national standard. On the whole, the color temperature in Taikoo Li gives people a warm feeling, and make the flow speed lower, which is conducive to commercial activities along the channel. The color temperature of Tianfu Square Fashion Shopping Center gives people a refreshing feeling, and the flow speed is faster than Taikoo Li. Considering the test channel has the function of the metro station passageway, the higher color temperature is beneficial to the flow rate and avoids channel congestion.

(a) The illuminance in all tested areas     (b) The color temperature and ground luminance in all areas

![Fig13. Relevant lighting parameters in all tested areas](image)

4. Conclusions
(1) The illuminance of underground shopping mall in Chengdu basically conforms to the national standard. The illumination of underground commercial shops’ lights can obviously enhance the illuminance value and floor luminance of underground corridors. In the areas which lack shops, the layout of lights should be strengthened.

(2) The introduction of natural light has obvious positive effects on the illuminance and luminance of underground space. It not only saves energy, but also eliminates the sense of depression in the underground space and provides a comfortable lighting environment. It is worthy of adoption and promotion. The planar lights are more advantageous than the point lights in illuminance value and
uniformity ratio of illuminance. The underground shopping mall should make full use of the characteristics of various types of light sources, combining the points, lines and planar lights to create a rich and comfortable underground environment.

(3) The color temperature of the light source in Sino-Ocean Taikoo Li Chengdu is 3000K, which is lower than the lower limit value recommended by the national standard. But the actual light environment is more comfortable than other underground shopping malls. Therefore, the selection of the color temperature should not be limited to the national standard, and the suitable color temperature should be selected according to the specific commercial orientation, decoration style and other related factors.

Acknowledgments
The work was supported by the Ministry of Education Science and Technology Industry-University Cooperation and Education Project (201801221005), Regional Public Management Information Research Center Grant Project (QGXH18-08), Sichuan Education and Scientific Research Grant Project (2018495), Chengdu Philosophy and Social Sciences Planning Project (2019R44).

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