RESEARCH ON GLARE OF TRAFFIC MONITOR SUPPLEMENTARY LIGHTING IN CAMPUS ROAD BY DOUBLE ILLUMINATION MEASUREMENT METHOD

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The influence of glare by traffic monitoring supplementary light has attracted wide attention. But it is too complex to direct measure and calculate according to the theoretical calculation method of threshold increment, because of the reality scene with complex light environment. This paper investigates the glare of traffic monitoring supplementary lighting in the campus of Chongqing University, by process the double method of measuring the overall illumination at first and then measuring the illumination after blocking the supplementary light. Through the analysis of the measured illuminance, the threshold increment of the glare of the monitoring supplementary light is calculated. The results show that the glare of the monitoring supplementary light greatly exceeds the requirements of the Urban Road Lighting Design Standard (CJJ45-2015). Therefore, there is a potential safety hazard in the traffic monitoring supplementary light, which needs to be adjusted to ensure safety. This research shows the double illumination measurement to calculate the glare threshold increment is convenient and feasible.

Keywords: supplementary illumination of road surveillance; illumination glare; threshold increment; equivalent veiling luminance; illumination measurement

1. Introduction

With the increasing of motor vehicle and human flow on campus, the traffic accidents occur frequently. In recent years, in order to realize the intellectualized construction and strengthen the campus traffic management, some colleges and universities have set up motor vehicle monitoring devices in key sections of road. In order to satisfy the need for monitoring cameras to clearly capture vehicle and license plate information at night, supplementary illumination equipment have been set up, which can produce sufficient supplementary illumination to take clear pictures at a distance of about 20 meters [1]. However, traffic monitor

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supplementary light has a strong glare on drivers, which has a negative impact on traffic safety.

Due to the limitation of relevant standards and the lack of glare control technology, there is a lack of effective method and measures to control glare. At present, the research on supplementary illumination of traffic monitoring mainly focuses on the application of supplementary illumination system lamps, design, and glare test method [2]. The research on the influence of supplementary illumination of road traffic monitoring on motor vehicle traffic at home and abroad is relatively deficient [3]. At present, when measuring according to the theoretical calculation method of threshold increment, it is necessary to measure the illumination value on the eyes of the observer with different glare light sources, and measure the angle between the line of sight and the light emitted by the glare light source into the eyes, then calculate the $\frac{E_{eye}}{\theta^2}$, formed by each glare light source in the eyes, and finally sum up and calculate the threshold increment [4,5]. The test method has high precision, but the operation is too complex, and it cannot control the glare light source on or off separately in reality. Therefore, it is not operable in the scene with complex light environment [6,7].

In this paper, double measurements method is used to study the glare effect of monitor supplementary lights when they are on and off. This method has the advantages of simple equipment and easy operation, and the calculation results accord with the driver's actual feeling. It provides a simple and easy evaluation method for rapid evaluation of the glare effect of monitor supplementary lights.

2. Research Foundation of Monitoring Supplementary Lighting Glare

2.1. Requirements for Monitoring Supplementary Lighting Settings

In order to avoid affect road traffic safety, the installation height of the road monitoring device above the road should not be lower than the height of the traffic lights, and the vertical distance between the installation height and the ground should be greater than or equal to 6 meters. The supplementary illumination of road monitoring can improve the illumination value of target objects in night or low illumination, in order to obtain good video screen and image quality [8]. China's public safety industry standards promulgated "Standard for Installation of Traffic Monitoring and Recording Equipment (GA/T 1047-2013)" [9] and "General Technical for Traffic Monitoring and Imaging Supplementary Light Device (GA/T 1202-2014)" [10]. It is stipulated in the specification that supplementary illumination can use either LED light source or gas discharge light source, or other light sources. The supplementary illumination modes include continuous illumination, stroboscopic illumination and pulse illumination. At present, continuous lighting and stroboscopic lighting are widely used in road monitoring supplementary lighting. Pulse lighting is forbidden to be used at night because of its strong glare interference.

2.2. Glare of Traffic Monitoring Lighting

Although there are few studies on the impact of glare by traffic supplementary light in the field of traffic safety, the research on glare itself has a long history at home and abroad. As early as 1926, American physicist Holladay put forward the concept of glare. Scientists have conducted in-depth research on glare evaluation. Four main glare evaluation expressions have been developed, namely the Unified Glare Index (UGR) for indoor environment, the Glare Value (GR) for outdoor sports venues, the Threshold Increment (TI) for road lighting and the Glare Control Level (G) [11,12].

Traffic monitoring supplementary light glare is a new glare hazard in recent years, which brings great hidden dangers to road traffic safety. Because of the high brightness of supplementary light in road monitoring, it has a serious glare effect on motor vehicle drivers. The existence of light curtain in human eyes reduces the contrast between target and background, affects driver’s visual function and brings potential safety hazards. Therefore, traffic monitoring supplementary light glare is a kind of disability glare. In the outdoor glare evaluation methods, both the glare value (GR) and the glare control level (G) are uncomfortable glare evaluation methods. Only the road illumination threshold increment (TI) is used to evaluate the disability glare, and its glare formation mechanism is similar to road illumination glare. Therefore, the road illumination threshold increment (TI) can be used to evaluate the glare effect of supplementary light.

2.3. Threshold Increment (TI) Evaluation Method

Threshold increment (TI) is a measurement to evaluate disability glare. In order to counteract the effect of equivalent screen brightness on visual perception and restore the contrast between object and environment in human eyes, it is necessary to improve the brightness of object. This brightness increment is called threshold increment (TI) [13-15]. The CIE technical report (CIE 140-2000: Road Lighting Calculation) recommended the method of evaluating and calculating the increment of road glare threshold. On this basis, the relevant scientific researchers have further studied. Usually when the brightness of road lighting is within the range of 0.05 -5 cd/m2, the threshold increment can be calculated by the following mathematical expressions:

$$\mathrm{TI} = 65\frac{L_v}{L_{av}^{0.8}}\ \% \tag{1}$$

there: L_{v}——Equivalent brightness of glare in the eye (cd/m^2);

L_{av} ——Average brightness of pavement (cd/m^2).

The equivalent brightness of the screen can be calculated by the following empirical formulas:

$$L_v = K\frac{E_{eye}}{\theta^2} \qquad (2)$$

there: E_{eye}——The illumination produced by a glare light source perpendicular to the line of sight of the observer's eye(lx).

θ——The angle between the line of sight and the incident direction of light from the glare source.

K——Proportional constant, $K = 10$ when θ is in degrees.

According to formula (2) to calculate the equivalent light curtain brightness, the illuminance value of the glare light source in the observer's eye and perpendicular to the line of sight plane must be determined by the solid angle projection law. See Figure 1 for the calculation diagram and formula (3) for the theoretical calculation.

$$L_v = K\int_0^{2\pi}\int_{\theta_1}^{\theta_2} L(\theta,\varphi)\frac{\sin\theta\cos\theta}{\theta^n}d\theta d\varphi \qquad (3)$$

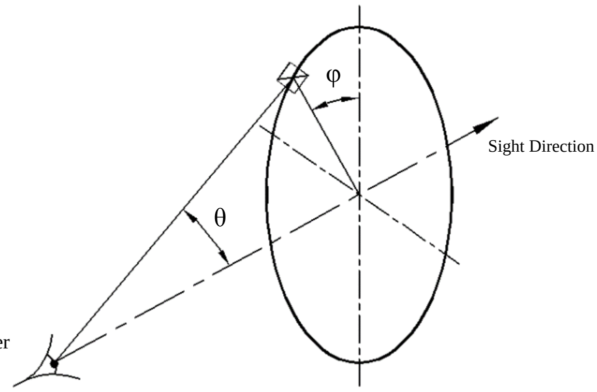

Fig.1. Equivalent veiling luminance calculation schematic diagram

When the average value of luminance in each ball belt is approximately as $L_{av}(\theta_i)$, formula (3) can be calculated as formula (4).

$$L_v = \frac{1}{6}K\pi\left(\sum\sum L_{ije}\right)\int_{\theta_1}^{\theta_2}\frac{\sin\theta\cos\theta}{\theta^n}d\theta \qquad (4)$$

The integral calculation in formula (4) is very troublesome and not suitable for on-site fast measurement and calculation, so it is necessary to adopt a more simple and quick measurement method.

There the driver observation height is 1.2-1.5 m, and the line of sight direction is 1° horizontally downward. And the observation area of the road area is 0.5° to 1.5° downward horizontally in the driving direction, which is equivalent to the area 60m to 160m in front of the road surface.

In the actual environment, it is very difficult to directly measure the illuminance produced only by the glare source on the driver's line of sight due to the influence of the surrounding ambient light.

3. Monitoring Distribution in Campus

In order to create a good traffic environment, the campus A and B of Chongqing University has set up traffic monitoring facilities on the main road. Among them, 7 are in Campus A and 5 are in Campus B (Fig. 2) (Table 1).

Table 1

Traffic Monitoring Setting in Chongqing University

No	Monitoring Point		Monitoring Number	supplementary lighting Number		Environment Description
				flash	continuous	
1	Main gate	Campus A	1	1	1	Street lighting nearby
2	Office building		1	0	1	Street lighting nearby
3	Library		1	1	1	Street lighting nearby
4	Graduate School		1	0	1	Street lighting in far distance
5	Gymnasium		1	1	1	Street lighting nearby
6	Film Academy		1	0	1	Street lighting in far distance
7	Back door		1	1	1	Street lighting weak
8	Main gate	Campus B	1	1	2	Street lighting nearby
9	Football field		1	1	1	Street lighting nearby
10	Complex building		1	1	1	Street lighting weak
11	Tunnel		1	0	1	Street lighting weak
12	Back door		1	1	1	Street lighting weak

The setting of road monitoring has played a good role in improving the campus traffic environment and controlling the campus speeding behavior. Because of the narrow campus roads, only one monitoring device was installed at each point. At the same time, in order to improve the monitoring effect at night, supplementary lighting equipment settings are equipped with monitoring.

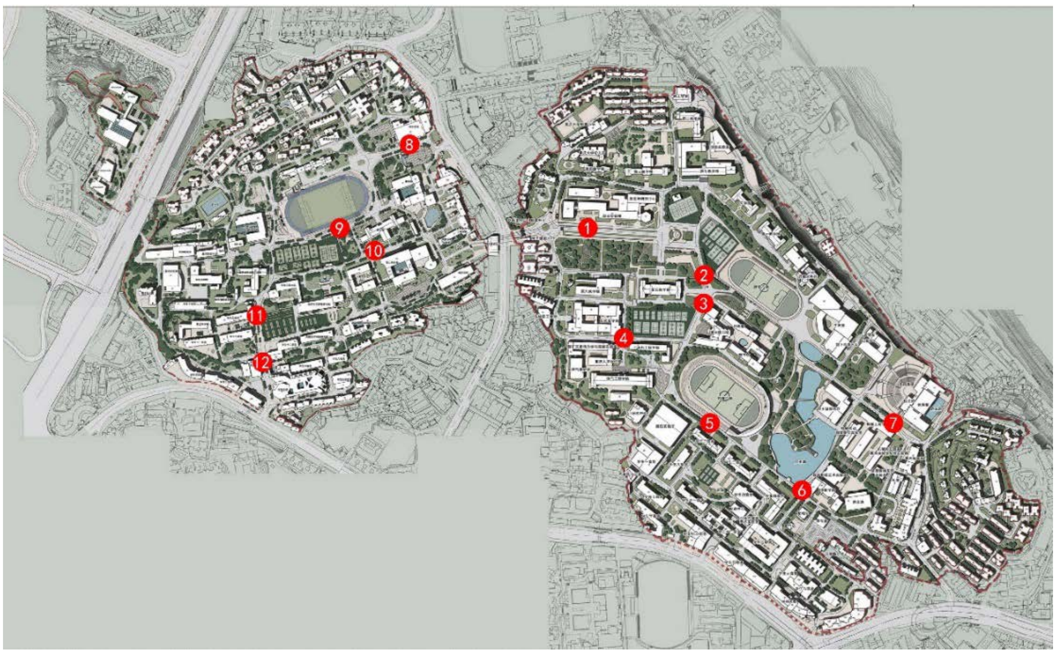

Fig. 2. Monitor Supplementary Light Map of campus in Chongqing University

The supplementary lighting equipment includes constant light and explosive flash, which works normally at night. Because of the strong glare, the flash lighting is not put into use, and the direction of illumination points above the horizontal direction (Fig. 3). Although there are only continuous supplementary lights, the glare is still very serious (Fig. 4).

Fig. 3. Monitor and Supplementary Light

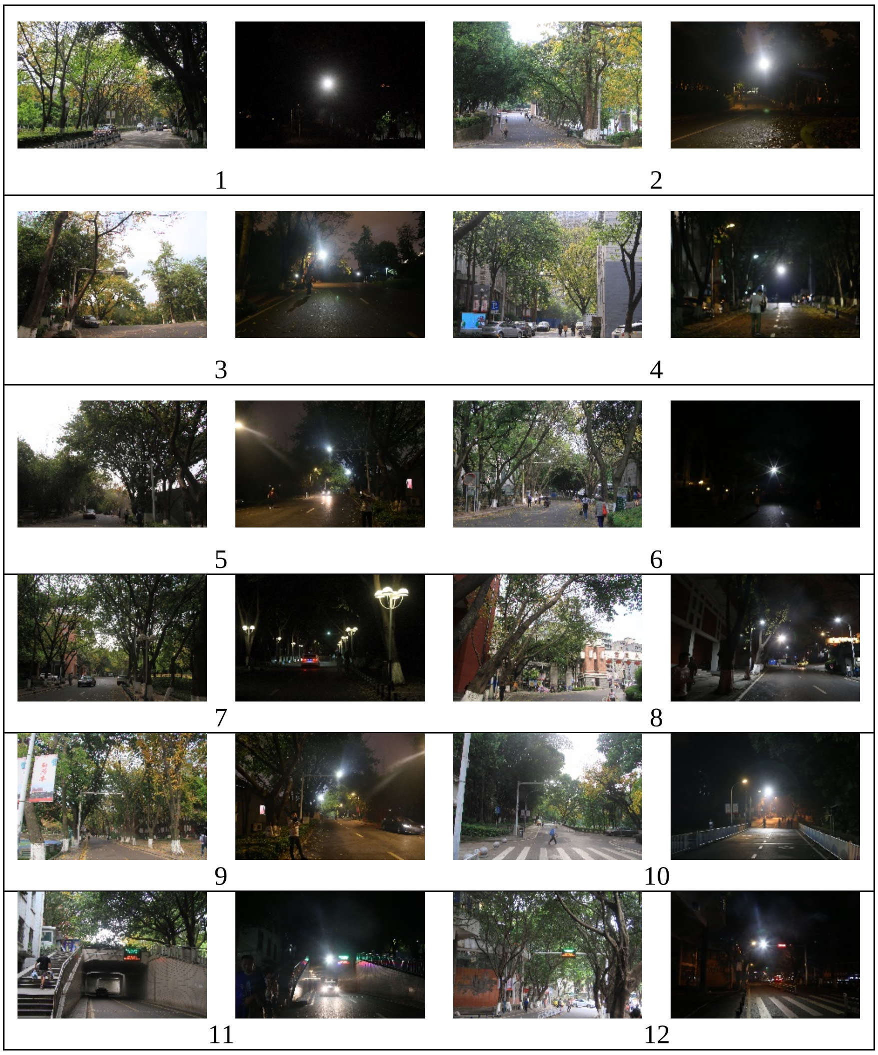

Fig. 4. Monitor Supplementary Light Working in Day and Night

4. Double Illumination Measurement Method of Monitor Supplementary Light Glare

The roads in Campus A and B of Chongqing University are mostly two-way lanes. The monitoring probe is located in the middle above the road about 5m, which can monitor two-way traffic. Most of the campus roads are illuminated unilaterally and covered by good greening trees, so the illumination effect of the roads is general. Because of the narrow road and the motor Lane in the campus is winding and winding, so the section entering the road traffic monitoring section and seeing the monitoring glare supplementary lamp is relatively short. Therefore, according to the actual situation of the scene, the glare effect within 50 meters of the traffic monitoring supplementary lamp is tested and studied.

4.1. Double Illumination Measurement Method

According to the theoretical calculation method, when measuring of threshold increment, it is necessary to find the illumination value on the eyes of the observer with different glare light sources, and to measure the angle between the line of sight and the light emitted by the glare light source into the eyes, then calculate the $\frac{E_{eye}}{\theta^2}$. After sum up each value of glare light source in the eyes, the threshold increment can be calculated. The test method has high precision, but the operation is too complex, and it cannot switch the control of glare light source on or off separately in reality, therefore, it is not operable in the scene with complex light environment. In addition, because of the complex light environment on the spot, the monitoring section is affected not only by the monitoring supplementary light, but also by the surrounding environment lighting. In order to study and monitor the glare effect of supplementary lights and eliminate the influence of ambient light of road lighting, double measurement methods are used to eliminate glare. The specific test methods are as follows:

- The measurement point is located on the right side and 1/4 width of the road, which simulates the driver's route and sight line (Fig. 5). The probe of the illuminometer is mounted horizontally forward with a height of 1.2m and an angle of 1° between the probe and the horizontal line. When the monitoring light is in stable, the total illumination E_{eye1} on the observer's eyes (illuminometer) is measured.
- The total illuminance E_{eye2} of the eye (illuminometer) without monitoring supplementary light is measured by using the black baffle shielding to the monitor supplementary lamp, and then the total illumination of the supplementary light is obtained by subtracting the illumination: $E_{eye} = E_{eye1} - E_{eye2}$.
- Using laser goniometer to measure the angle θ between the line of the supplementary lamp and sight.
- Using calibrated digital camera to test the average brightness value of road surface L_{av}.
- Threshold increment (TI) approximation of the position is calculated by formula 1. In order to obtain the effect of glare monitoring at different positions, a measuring point is set every 5 meters.

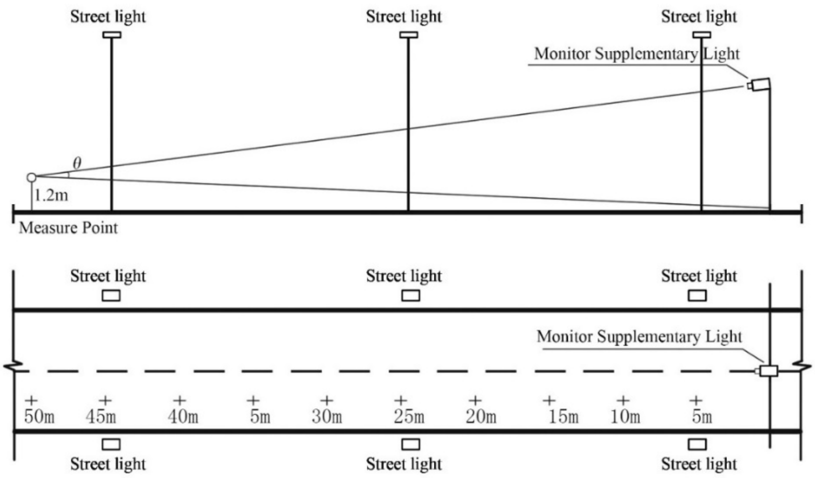

Fig. 5. Field Test Schematic

4.2. Measurement and TI Result

The measure test time is April 23 and April 24, 2018. In order to reduce traffic interference, the test time is after 00:00 a.m., when the number of vehicles on campus is few. The test is carried out in the order of monitoring points listed in Table 1, and the test method is carried out in accordance with the method of 3.1. The final test results and data input are calculated in a pre-programmed program, and the approximate value of glare threshold increment (TI) is obtained for each measuring point. The glare TI produced by each measuring point is compared, and the largest glare TI is selected as the glare TI of the monitoring supplementary lamp (Table 2).

Table 2

Maximum threshold increment (TI) of glare in monitor point

No	Monitoring Point		Distance (m)	Threshold Increment (TI)(%)	Standard (CJJ45-2015) (%)	Judge
1	Main gate	Campus A	56	56	10	Exceed
2	Office building		139	139		Exceed
3	Library		55	55		Exceed
4	Graduate School		241	241		Exceed
5	Gymnasium		22	22		Exceed
6	Film Academy		88	88		Exceed
7	Back door		68	68		Exceed
8	Main gate	Campus B	106	106		Exceed
9	Football field		89	89		Exceed
10	Complex building		73	73		Exceed
11	Tunnel		125	125		Exceed
12	Back door		41	41		Exceed

Due to the different time of monitoring settings and the different functional lighting settings in different regions, the final glare threshold increment (TI) values are obviously different. From Table 2, it can be seen that the glare index of the supplementary lights for road in Campus A and B of Chongqing University is 22% at the lowest level and 241% at the highest level, which are much higher than the Standard. While the increment of the glare threshold of the secondary road in the Urban Road Lighting Design Standard (CJJ45-2015) is only 10%.

In addition, the area with the most incremental glare threshold is 20 to 35 meters away from the supplementary light, which is basically distributed near the axis of the supplementary light.

4.3. Result Analysis

This research is the result of eliminating the influence of street lights and neglecting the headlamp. If the glare problem of street lights is considered, the glare effect will be more serious, and it will bring great potential safety hazards to the traffic safety. Therefore, the influence of the glare of monitoring supplementary lights on road safety cannot be ignored.

From the principle of glare threshold increment, in order to reduce the glare threshold increment, we can start from two aspects, that is, to reduce the equivalent light curtain brightness of human eyes or to increase the average brightness of road surface.

Equivalent screen brightness L_v is affected by line-of-sight direction E_{eye} and θ, while E_{eye} is affected by the requirement of vertical illumination for surveillance camera photography and cannot be reduced significantly before the performance of the equipment is greatly improved. Therefore, the glare effect can only be reduced by increasing θ value. Therefore, it is a feasible method to change the hanging height and tilt angle of the supplementary lamp, and further research is needed in the later stage.

The increase of road brightness will reduce the increment of glare threshold, which also can enhance the monitoring effect, and weaken the glare effect of monitoring supplementary lights.

Due to the lack of theoretical research between monitoring supplementary glare and driver’s visual response, traffic management departments cannot effectively control and rectify the monitoring glare, which makes the problem of monitoring glare still widespread. Therefore, in the future, we should strengthen the basic research on the mechanism and effect of road monitoring glare on driver’s visual response, and provide theoretical basis and technical support for glare control. At the same time, we should conduct in-depth research on the glare evaluation method of monitoring supplementary lights and find a simpler and easier-to-use evaluation method.

5. Discussion

The recommended method of CIE (CIE 140-2000: Road Lighting Calculation) is complex, and the separately measurement of light source cannot switch in real environment. But the double measurement method in this paper is simpler and easier to use in the actual conditions.

The TI in Urban Road Lighting Design Standard (CJJ45-2015) is 10%. In this paper, the TI values of the school road traffic monitor supplementary lighting calculated by double measurement methods are all over the standard, which will affect the driver's vision and cause safety hazards.

There are two types of monitor supplementary lighting lamps: constant and pulse. While this paper only researched constant lamps. And their effects need to be further discussed in future research.

6. Conclusions

In this paper, double measurements method is used to study the glare effect of monitoring supplementary lights when they are on and off. At present, the glare index of road monitoring supplementary lights in campus of Chongqing University reaches 22% to 241%, which is much higher than the value 10%, that is allowed increment of glare threshold of secondary road in "Urban Road Lighting Design Standard (CJJ45-2015)". This method has the advantages of simple equipment and easy operation, and the calculation results consistent with subjective actual feeling.

This research shows the double illumination measurement to calculate the glare threshold increment is convenient. Found by this research， future research on how to reduce the influence of traffic monitoring supplementary light glare, and the mechanism of glare effect and drivers' visual response should be feasible and more convenient.

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