Journal of Research in Multidisciplinary Methods and Applications (JRMMA)
ISSN: 2957-3920, Volume 1, Issue 2, June 2022

Development of A Lighting System for Tunnels Based on Energy Storage Luminescence Coatings

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Abstract*: Using the light absorption-luminescence characteristics of energy storage luminescent materials, in view of the existing tunnel lighting system energy consumption, glare on the driver and passenger safety hazards and other issues, self-made corresponding paint, in the case of physical and chemical performance testing compliance, with LED excitation lamp and water pattern projection lamp The practical application in the Huangjiawuji Tunnel of Lanhai Expressway has achieved an effect superior to that of traditional lighting methods, and it has been evaluated that the lighting system based on energy storage luminescent coatings can be widely promoted in tunnel lighting.*

Keywords: tunnel lighting; energy storage luminescent coating; preparation process

0 Introduction

With the rapid development of China's economy, the highway mileage has increased rapidly, and the highway tunnel mileage has also increased significantly, especially in mountainous areas, the length of the highway tunnel has even reached 30% of the length of the highway in some areas. Tunnel lighting is one of the most important infrastructures for road traffic safety and is of great significance to driving safety [1-3].

The traditional solution is usually to install a large number of lights, but it is necessary to turn on these lights 24 hours a day, all year round, which will consume a lot of power resources. In order to reduce the consumption of lighting electricity in tunnels, paints of energy storage luminescent materials have been gradually used to replace lighting lamps in highways and road tunnels. The so-called energy storage luminescent material, as the name suggests, is to absorb the energy of the external light source, the use of the material itself characteristics to store part of the energy, followed by the release of visible light, the process is relatively slow, so in the absence of light conditions can be emitted for a long time [4], the advantage of the energy storage luminescent material is that the excitation - luminescence process can be carried out indefinitely. Matsuzawa et al. [5] used SrAl2O4 to explain the working principle of energy-storing luminescent materials, arguing that electrons undergo a ground-state-to-excited state transition to store energy when excited by an external light source When excitation is stopped, the electrons and holes are compounded by the migration of the hole ad valence band to the excited state, resulting in a long afterglow glow [6-8].

The existing schemes can play a certain role in tunnel lighting, but because the brightness of the self-luminescent material after storage will continue to decay within a certain period of time, it cannot play its role efficiently, such as the energy storage luminescence of the aluminate system, the initial luminous brightness> is 2000 mcd/m2, and the luminous brightness after ten minutes> is 200 mcd/m2, After 60 minutes the luminous brightness> is 50 mcd/m2, and after 120 minutes the luminous brightness is> 20 mcd/m2, and the afterglow time is greater than 12 hours, but in real life, when the brightness is less than 200 mcd/m2, the driver's visual perception is relatively low. Although the lights driving through the tunnel can supplement a part of the external input light energy, it is still necessary to supplement the light energy through the main lighting of the tunnel to maintain the luminescence of the energy storage luminescence material.

Therefore, this paper designs a complete set of road tunnel solutions based on energy storage light-emitting coatings for this problem.

1 Test Section

1.1 reagent

The main components include: 3W cellulose, multifunctional additives, defoamers, ethylene glycol, wetting agents, dispersants, calcined kaolin, rutile titanium dioxide, heavy calcium, dodecanol esters, anti-mildew preservatives, LR303 and thickeners.

1.2 preparation of test samples

The use of asbestos-free fiber cement board as the substrate should comply with the corresponding provisions of JC/T 412.1-2006 and be treated in accordance with the provisions of GB/T 9271. The energy storage luminescent material is stirred evenly and then the plate is made.

1.3 physical performance testing

Water resistance, alkali resistance, acid resistance test, artificial climate aging test.

1.4 detection of luminous brightness and afterglow time of energy storage materials

Detection by illuminance measuring instrument: measuring range is 10~1×105x, resolution is 1x; The diameter of the photosensitive surface of the metering probe is 8-12mm; The measuring range is 0.01 mcd/m2 to 2×106 mcd/m2. The test time shall not exceed 1440min.

2 Results and Discussions

2.1 plate preparation

Samples are made from a wire rod applicator made of stainless steel. The wire rod coater should be made of several different diameters of stainless-steel wire tightly wound on the stainless-steel rod, and its specifications are 80, 100, 120, and the wire rod specifications The corresponding wound wire diameter is shown in Table 1.

Table 1 Wire rod specifications correspond to wire diameters

specification	80	100	120
Wound wire diameter/mm	0.80	1.00	1.20

Use a brush to apply the specimen on a horizontally placed test board with a wet film thickness of about 100μm, so that the long side of the test board is horizontal, and the short side is placed vertically at an angle of about 85° with the horizontal plane. After 6h of placement, the second specimen is painted in the same way. When the brush is applied in the second brush, it can be rated as "brushing and coating barrier-free".

The type, size, quantity, coater specifications, number of coating channels and maintenance time of the test plates of each inspection project should comply with the provisions of Table 3. When coating two lanes, there is at least 6h space between the two lanes. When there are supporting products, samples should be prepared according to the manufacturer's instructions, and the construction interval of each channel is 6h.

Table 2 Plate making requirements

Inspection project	Platemaking requirements					
	Substrate type	Substrate size/mm	Quantity/block	Wire rod applicator specifications		Curing time/d
				The first way	Second way	
Drying time	Asbestos-free cement flat	150×70×(4～6)	1	100	-	-
adhesion			1			7
Constructability, coating appearance		430×150×(4～6)	1	Paint 2 times		-
Fire resistance, alkali resistance, acid resistance, coating temperature resistance, visible light reflectivity, stain resistance, artificial climate aging resistance		150×70×(4～6)	3 each	120	80	7
Brush resistance		430×150×(4～6)	2			
Before the sample preparation, the white paint is pre-applied twice, and the reflectivity of the paint film should be (85±2)%.						

2.2 water resistance, alkali resistance and acid resistance test

Immerse the prepared panels in a glass sink where 23±2 °C of warm water is allowed and the water temperature is maintained so that 2/3 of the length of each plate is immersed in water.

The three test plates tested did not appear in the national standard requirements of discoloration, foaming, powder loss and other phenomena, in accordance with the GB/T 1733-1993 requirements, energy storage luminescent coating water resistance compliance.

At a temperature (23±2) °C, Ca(OH)2 was added to tertiary water to prepare an alkali solution, and after a closed place for one day and night, the upper layer of supernatant was taken as a test solution, and the test plate was sealed Put the back into the above alkali solution, and 2/3 of the plate length should be immersed in the solution.

The three test plates tested did not appear in the national standard requirements of discoloration, blistering, peeling, chalking and other phenomena, in accordance with the requirements of G B/T 9265-2009, energy storage luminescent coating alkali resistance compliance.

At a temperature (23±2) at a temperature of 500 mL, stir in 500 mL of water to add 6 mL H2SO4 (98%) 、3mL HNO3(65%～68%) 、1mL HCl (36% to 38%), formulated into a mixed acid solution, and added a mixed acid solution in an appropriate amount of water to prepare a pH = 3 0 acid solution. Put the back of the plate seal into the above alkali solution, and 2/3 of the plate length should be immersed in the solution.

The three test plates tested did not appear in the national standard requirements of foaming, powder loss, obvious discoloration and other phenomena, in accordance with the requirements of GB/T 9274-1988, energy storage luminescent coating acid resistance compliance.

The test results of water resistance and alkali resistance and acid resistance are shown in Table 3.

Table 3 Water resistance, acid resistance, alkali resistance and acid resistance test

	bubble	Drop the powder	discoloration
Resistant to water	not	not	not
Alkali	not	not	not
Acid	not	not	not

2.3 determination of luminous brightness and afterglow time

Using the D65 standard light source as an excitation light source, directly irradiate the coating surface with a certain illuminance, and turn off the light source after irradiation to the specified time. The brightness value of the coated film surface at different times after the irradiation stop is tested by the luminescence photometric measuring instrument, that is, the luminous brightness; The time that lasts from the time the excitation light source stops to when the luminous brightness drops to 0.32 mcd/m2 is the afterglow time.

Excitation light source Select D65 light source, after turning on the light source, place the test pad in the center of the test plate illuminated area and at 4 points at the outer edge of the test plate surface that are 90° each other. There should be no external light source and environmental stray light source in the test environment, and the temperature should be

maintained at 24 °C.

The test plate is placed into a specific sample dish so that the excitation light source is directly irradiated on the energy storage coating film, stopped after 5 min, and the time of excitation stop is recorded T1, and the luminous brightness of the test plate after 10 min after excitation stop and excitation stop at 1h, the luminous brightness of the test plate, when the luminous brightness drops to 0 At 32mcd/m2, record time T2. Calculate the afterglow time according to Equation 1:

$$T_y = T_2 - T_1 \quad (1)$$

Wherein:

Ty - afterglow time, in hours (h);

T1 - the time at which excitation stops, in single bits (h);

T2 – Luminous brightness reduced to 0 32 mcd/m2 time in hours (h).

The results are shown in Table 4.

Table 4 Determination of excitation brightness and afterglow time of energy storage luminescent coatings

Luminous brightness /mcd/m2	Excitation brightness	1min≥16cd
	Excitation stop brightness (close)	1min≥250mcd
	Excitation stop brightness (close)	1h≥12mcd

2.4 resistance to artificial climate aging

The so-called artificial climate aging refers to the change in the performance of energy storage coatings during artificial climate aging or artificial radiation exposure. Artificial climate aging of the coating is carried out by the hernia arc light filtered by the filter, the purpose of which is to make the coating undergo a certain degree of exposure radiation energy, so that the selected properties produce a certain degree of change, or to make the coating reach a certain degree of aging required exposure radiation energy.

The sample was wetted in a periodic cycle as shown in table 5, during which radiation exposure was uninterrupted and the test time was 1000h.

Table 5 Test process for artificial aging resistance of energy storage luminescent coatings

circulate	Operating mode	Wetting time/min	Drying time/min	Relative humidity /% during drying
Time	Continuous operation	18	102	40-60

After the end of the test, the physical appearance of the sample, such as chalking and discoloration, is detected, and the results are shown in Table 6, and the luminous brightness decline rate is detected according to Equation 2

$$X = \frac{A-B}{A} \times 100\% \quad (2)$$

Wherein:

X - coating luminous brightness reduction rate, %;

A - the initial luminous brightness of the coating (when the irradiation stops for 1h), unit mcd/m2;

B - The luminous brightness of the coating after the artificial climate elderly industrialization test (when the irradiation stops for 1h), the unit mcd/m 2。

Table 6 Detection of artificial climate aging resistance of energy storage luminescent materials

appearance	Chalking / level	discoloration / level	Luminous brightness decrease rate /%.	Afterglow time/h
Non-foaming, non-flaking, no cracking	≤1	≤2	≤20	≥10

2.5 practical engineering applications

Through the above testing, the physical and chemical properties of the energy storage luminescent coating obtained meet the national standards and meet the actual use needs, so in the lanhai expressway Chongqing to Zunyi section expansion project of the ultra-long tunnel lighting project, it was selected to carry out the "tunnel driving comfort transformation" project test in the middle section of the "Liuwei Expressway" Huangjiawuji tunnel. The total length of the Huangjiawuji Tunnel is 1978m, and the project is set as the 600-meter area section of the tunnel in the middle of the tunnel pile YK16+218~YK16+818, before and after the area 50m (i.e., YK16+155~YK16+205 and YK16+828~YK16+878) serves as a soothing transition section for tunnel driving, with LED Engineering testing of excitation lamps and water-streaked projection ceilings. The actual effect of the tunnel is shown in Figure 1. After the acceptance of the engineering designer Guizhou Expressway Group Co., Ltd., it meets the requirements of highway tunnel construction and has the following advantages compared with the commonly used ordinary LED lamps:

Table 7 Advantages of tunnel lighting systems based on energy storage luminescence coatings

	Common LED products	Energy storage luminous products
life span	20000 hours (phototension).	20,000 hours + light storage material to compensate for light decay
Innovative	Conventional tunnel LED lighting	Soothing lighting
Reflective	One-time glow	Secondary reflection
Glare	Glare is present	There is no glare

Fig. 1 Renderings of the "Tunnel Driving Comfort Transformation" of the Huangjiawuji Tunnel

3 Conclusion

(1) Self-formulated energy storage luminescent coating for tunneling;
(2) In accordance with the corresponding national standards, its physical and chemical properties meet the requirements;
(3) In the actual engineering application of the Huangjiawu foundation tunnel, with the excitation lamp and the water pattern lamp, the effect is smaller than the traditional tunnel lighting equipment and the cost is low.

Funds

Fund Project: Guizhou Provincial Science and Technology Plan Project (Qiankehe Support [2021] General 320). Guiyang Baiyun District Science and Technology Plan Project (Baike Contract [2020] No. 35).

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