Experimental research on daylight performance of side lighting light pipe*

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Abstract: Natural daylight has more and more been used in modern buildings to save building energy consumption in China. Light pipe is one of the effective way to reduce electricity consumption for lighting, it can transmit light from outdoor to the room without generating excessive heat. Experimental apparatus of side lighting light pipe is described in this paper. Light pipe for side daylighting purpose was installed in the Key Laboratory of Enhanced Heat Transfer and Energy Conservation, Ministry of Education, Beijing University of Technology. It was 2.6m long, with diameters of 360mm.The performance of the light pipe for whole day had been measured. The highest illuminance was 488lux on Dec.26,2002, obtained from the point beneath the center of the diffuser of the light pipe 1450mm. The ratio of internal illuminance to external was 0.23 %. Because it has many advantages to improve energy efficiency in buildings, light pipe will be popularized in the near future in China.

Keywords: sustainable energy; green lights; light pipe; illuminance

1.Introduction

Now the existing building area of the whole urban and rural area in China was over 36 billions square meters, and building energy consumption was 27.8% of the total energy consumption[1]. Compared with developed countries of similar climate conditions, the energy consumption per unit heating area of residential buildings in China was three times that of the developed countries. So developing sustainable energy technologies is one urgent thing in China. The Green Lights is one important aspect in making effective use of energy in implementing the sustainable development strategy and improving the environmental quality of human being's actives. Electricity consumption for lighting has a great proportion in the country's total electricity consumption. Recently, the proportion was about 10~12% in China. In 2001, the total electricity output was 1433.25 billions kWh, while the lighting consumption was about 143.325~171.99 billions kWh, which was twice the finished Three Gorges'. (The Three Gorges Project was ongoing) So, reducing electricity consumption for lighting was of special importance. On January 1,1998, Energy Conservation Law was established, including saving energy for lighting. Extending Green Lights greatly can save electrical energy accordingly. Therefore, it can reduce environment pollution caused by electricity generating. Standard for Day Lighting Design of Buildings (GB/T 50033-2001) and Design Standard of Civil Building Lighting(GBJ 133-90) had been promulgated. Light pipe technology is one of the methods of green lights. Light pipe is a proficient device for introducing daylight into buildings, especially cellar, corridor, lavatory, gloomy rooms.

Light pipes not only can reduce electricity consumption in buildings, but also can improve the indoor environment quality. In 1996, Bouchet found that as little as 50lux of daylight might reduce the feeling of isolation of people working in the coal mine or underground spaces who rarely see the daylight[2]. Light pipe system commonly has three components: an outside collector which is usually on the roof, the light pipe body itself and a diffuser which can releases the daylight uniformly into the room. The outside collector is a hemisphere usually made up of polyethylene. The light pipe itself is an empty tube of which highly reflective materials were coated on the internal surface and the external surface is usually made up of aluminium. The diffuser is often made up of plastic.

2.Experimental setup

The experimental apparatus for side lighting light pipe sketched as figure 1.The total length of light pipe was 2.6m and the diameter was 360mm,giving an aspect ratio of 7.2. It was quite different from the

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commercial one, which was commonly 1.2m long. It was installed in the Key Laboratory of Enhanced Heat Transfer and Energy Conservation, Ministry of Education, Beijing University of Technology. The size of the testing room was 4.2m×2.5m.

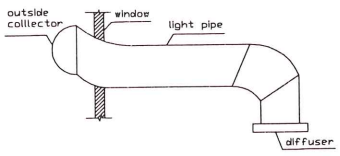

Fig.1. Schematic of light pipe experimental apparatus

Fig. 2 was the plan of the measuring sites of illumination in the room. There were fifteen measuring sites. The test section was 4 m×1.4 m. The distance between the measuring sites and the floor was 70mm.

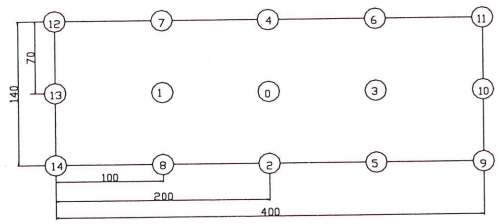

Fig. 2. The plan of measuring sites in the testing room

On the diffuser there were five measuring sites of which one was set on the middle of the diffuser and the others on four edges. Beneath the diffuser there were three measuring sites, which separately had a distance from the middle of the diffuser 40mm, 80mm and 120mm respectively. At the same time, the external illumination was also measured.

3.Results and discussion

The measurements were carried out on Dec.26, 2002. It was a sunny day. Figure 3 was the external illuminance curve. At 12:50 there was some cloud shading the sun which was reflected in the results from Figure 3. The highest illuminance was 52900lux, obtained at 12:05.The lowest illuminace was 396lx, obtained at 16:50. From 15:20, the external illuminance decreased rapidly.

The illuminance reading over the day at each measuring site was shown in Fig. 4. The window shade was shut when measurements were taken in the testing room ensuring that no external light and other light could enter the room, except through the light pipe. It must be ensured that no shadows fell on the sensor of illuminance meter during each measurement. The highest internal illuminace was 488lux obtained at 11: 20, the lowest illuminace was 0.47lux, obtained at 16:50.The values of measuring site "0" was much more bigger than other 14 measuring sites because it was the nearest one under the diffuser of light pipe, it was vertical to the diffuser. The lowest values always appeared at site "11" which was at the corner of the testing room and it was far away from the middle of the diffuser. Measuring sites "1", "2", "3", "4" were around site "0" and nearly proportional spacing. So they were showing higher illumination values.

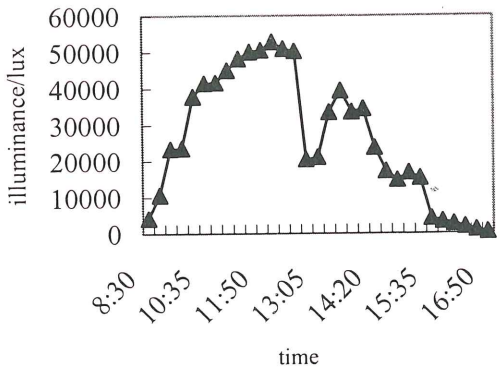

Fig. 3. External illuminance curve

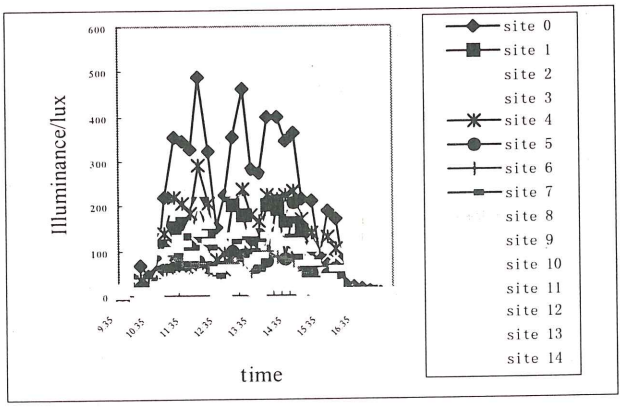

Fig.4. Internal illuminance curve

The average internal illuminance curve was shown in Figure 5. The highest internal illuminace was 129lux obtained at 13: 35, the lowest illuminace was 0.47lux, obtained at 16:50.From 15:05, the internal illuminance began to decrease rapidly because the west building near the laboratory was higher than the laboratory building so that sheltered from the sunlight on the outside collector. According to the Design Standard of Civil Building Lighting(GBJ 133-90), the illuminance generated by the side lighting light pipe could give better luminous environment for office, showroom, assembly room, reception room. In these buildings, the standard maximum illuminance is 200 lux and the

standard minimum illuminance is 100 lux according to the national standard of China.

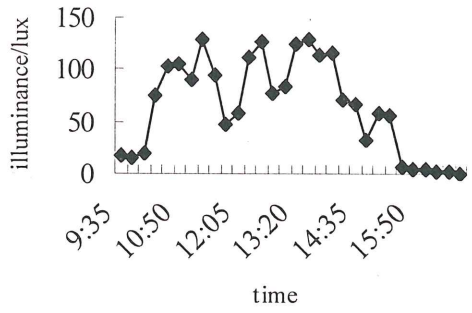

Fig. .5. Internal average illuminance curve

According to Figs. 4 and 5, If worksite was near the diffuser, the illumination effect would be better. It was enough to read newspaper or write something under the light pipe especially in sunny days. Even if it was a cloudy day, that was enough for reading.

The average illumination ratio of internal to external of light pipe was 0.23%, according to Figure 6. It was smaller because the length of the light pipe was bigger than the usual. The illuminance figures of the measuring sites follow the external illuminance values in the most conditions

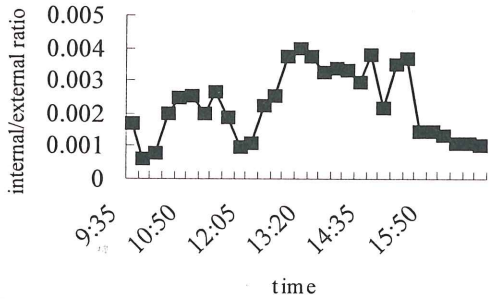

Fig. 6. The internal/external ratio

Average illuminance on the diffuser was shown in Fig. 7.It was about 51 % that of external average illuminance. Illuminance of the sites with the distance of 40 cm, 80 cm and 120 cm under the diffuser were shown in Fig. 8 as a reference.

The big difference between the internal and external value and the low ratio of internal to external were due to the losses during the light transmission caused by the nonstandard optics surface and the impure optics material. The longer the light pipe is, the greater the losses become. These problems need to be solved in the near future

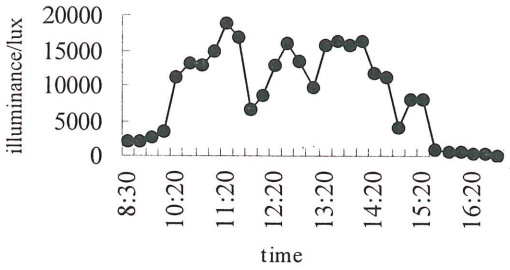

Fig.7. Average illuminance on the diffuser

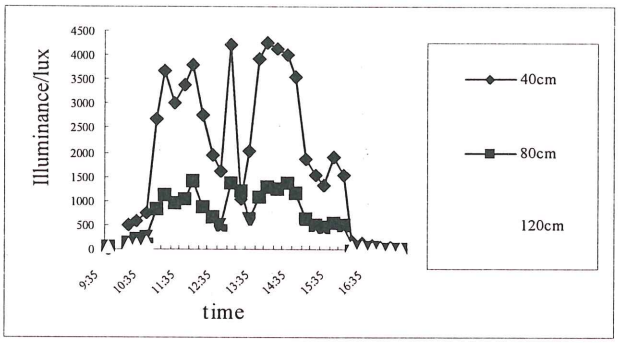

Fig. 8. Illuminance under the diffuser

4.Conclusions

Light pipe technology gives an effective way to transmit sunlight into room. It is much better as an auxiliary lighting method in buildings which are short of daylight. Through the experimental research on side daylight light pipe, the big difference between the internal and external value and the low daylight factor were due to the losses during the light transmission caused by the nonstandard optics surface and the impure optics material. The longer the light pipe is, the greater the losses become. Side lighting light pipes are usually longer than light pipes fixed on the roof and they can not achieve full sunlight than these roof ones. So daylight effect of side lighting light pipe is not the same as light pipe on the roof. But the illuminance generated by the side lighting light pipe could give better luminous environment for office, showroom, assembly room, reception room in China.

The experimental investigation is the primary research on light pipe. Further research has been going on. Light pipe combined with nano photocatalyst technology have achieved some progress in experiment and theory. This technology will bring not only good luminous environment but also better indoor air quality. Light pipe can also integrated with natural ventilation as light-vent pipe which had been researched in several countries such as UK and Portugal[2,3,8].

Light pipe is a sustainable energy technology and very effective green lights technology. With the development of energy efficiency in buildings and the improvement of life quality of Chinese people, daylight using light pipe will be popularized in the near future in China.

5.Acknowledgements

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