Test Report :

TRANSMITTANCE OF LARGE DIAMETER LIGHT PIPES UNDER OVERCAST AND SIMULATED SUNLIT CONDITIONS

Test report number 248038

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Summary

BRE was commissioned by SolaLighting to measure the light transmittance of two large diameter light pipes under overcast sky and simulated sunlight conditions. These were the Solalighting Solatube Optiview 530mm pipe, and the same diameter pipe from Monodraught.

The Solalighting Solatube Optiview 530mm pipe had a significantly higher transmittance than the Monodraught one.

Under simulated sunlight conditions, the transmittances followed a similar pattern to those under overcast skies.

Contents

1 Introduction

BRE was commissioned by SolaLighting to measure the light transmittance of two large diameter light pipes. The pipes are listed in Table 1.

Table 1: Details of the light pipes measured

Make	Type	Diameter	Actual length m	Overcast sky test?
SolaLighting	Solatube Optiview	530mm	2.4	√
Monodraught	Sun Pipe	530mm	2.4	√

Both pipes had a single glazed dome.

The light pipes were to be measured under simulated sunlight at three different solar altitudes, and also measured under overcast conditions.

All the light pipes were provided and assembled by Ian Bell, Chris Taffs and Omar Samaloussi of SolaLighting. Each pipe was 2.4 metres long. Each pipe was measured with the top dome and bottom emitter/diffuser in place, so the transmission factors given are those for the entire system. The SolaLighting pipe had an integral reflector designed to pick up more light at low sun angles; all measurements with this pipe were made with the reflectors set at the optimum angle.

The transmission factor T is defined as the light emitted from the light pipe system divided by the light entering it. The total light F emerging from the system in lumens is given by F = E T A where A is the aperture area (πr^2 for a circular pipe) and E is the illuminance at the top of the pipe (the global horizontal daylight illuminance for a vertical pipe). Use of the transmittance as a parameter allows the effects of pipes of different radii to be compared objectively.

2 Details of tests carried out

2.1 Use of the integrating box

Light can exit the light pipe in a range of directions. To ensure all the light is collected and accounted for, a photocell inside an integrating box is used (the ‘BRS Integrating Sky Photometer’). Figure 1 shows the box, which is painted matt white inside.

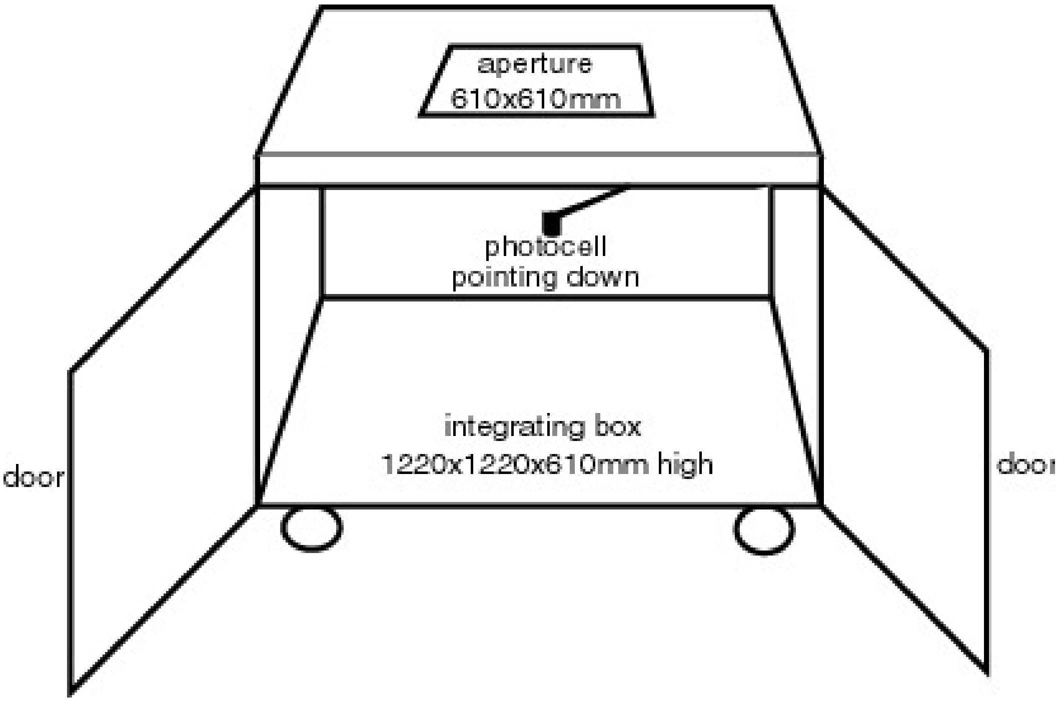

Figure 1 Integrating box used for the measurements. The doors are shut when in use.

During use, the doors to the box are shut and the light inside is measured using a colour and cosine corrected photocell attached to an LMT Lichtmesstechnik Pocket Lux illuminance meter. The photocell points downwards so it receives light from all directions, diffusely reflected inside the box.

The box is usually used to measure the diffuse transmittance of rooflight glazing. The photocell illuminance is first measured with the top aperture open. Then the rooflight sample is placed over the aperture and the illuminance remeasured. The rooflight transmission is the ratio of the illuminance with the rooflight divided by the illuminance without the rooflight. Hopkinson, Petherbridge and Longmore describe the technique on page 352 of their book ‘Daylighting’ (Heinemann, London, 1966). A similar procedure is recommended in BS EN1013-1 1998 ‘Light transmitting profiled plastic sheeting for single skin roofing: general requirements and test results’. For rooflights the measurement is usually made under an electrically lit simulated sky (an ‘artificial sky’) to ensure stability of illumination.

For light pipes, two modifications were required to the procedure. The diameter of the pipes is smaller than the normal aperture, so special aperture plates were constructed with a circular hole approximately equal to the diameter of the pipe. The ratio of the illuminance in the box with the pipe (Figure 2) to that with the aperture plate (Figure 3) then corresponds to the transmittance of the pipe system.

The 530mm Solatube is a round pipe that is usually fitted with a larger, square diffuser that is intended to replace a 600mm ceiling tile. For this system the test with the tube was carried out with a flat ‘Optiview’ diffuser and a circular aperture plate approximately equal in diameter to the top of the Solatube. This allows the actual amount of light exiting the tube to be compared with the light entering it.

Because of the length of all the pipes tested, the overcast sky measurements could not be carried out under the BRE artificial sky and were instead undertaken under the real sky (see next section).

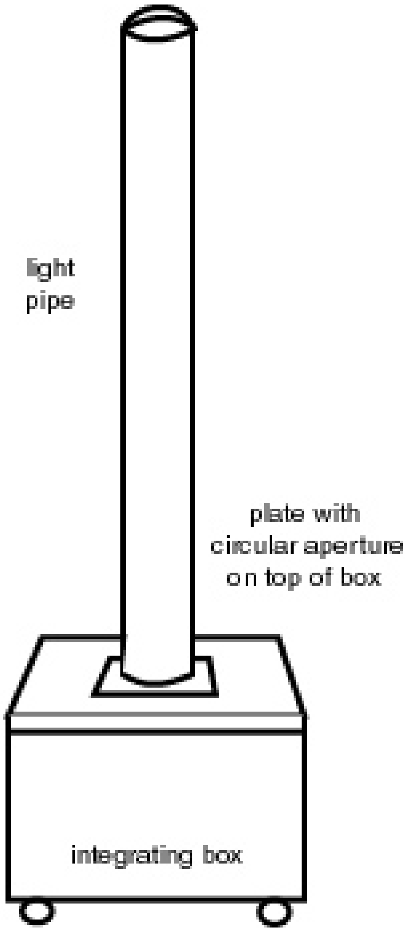

Figure 2 The light pipe seated on the integrating box.

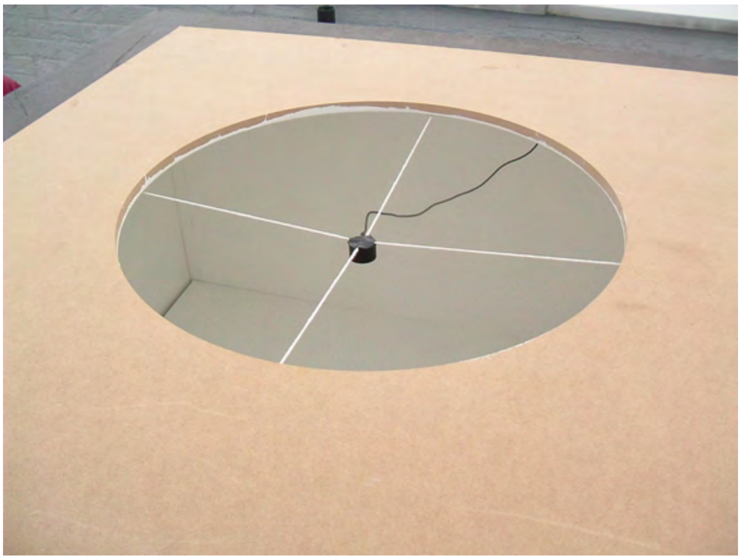

Figure 3 The aperture plate on top of the integrating box. The back of the photocell is visible through the aperture. The underneath of the plate is painted matt white.

2.2 The overcast sky measurements

These measurements were made on 12th and 24th September 2008 on the roof of building 9 at BRE. The roof is almost completely unobstructed. During the measurements the sky was completely covered in cloud, and the solar disk was invisible.

The illuminance was first measured in the integrating box with the aperture plate and no pipe. This was repeated with the pipe in place (Figure 4 illustrates this procedure), then with the aperture plate and no pipe again. However during the time taken to lift the pipe on and off the box the illuminance from the sky could change. This was corrected for by monitoring the unobstructed global horizontal illuminance using a separate LMT Lichtmesstechnik illuminance meter at the other end of the roof (Figure 5).

The transmittance of the light pipe was then taken as

$$T = \frac{\text{Illuminance in box with pipe}}{\text{Illuminance in box no pipe}} \times \frac{\text{Unobstructed illuminance for no pipe measurement}}{\text{Unobstructed illuminance for pipe measurement}}$$

Measurements were repeated for the different pipes.

Figure 4 Light pipe under test on roof

Figure 5 Simultaneous measurement of external horizontal illuminance using a separate light meter.

2.3 The simulated sunlight measurements

These measurements were made on 30 and 31 July 2008 inside the Structures Laboratory at BRE. This is a tall space surrounded by balconies. It has no windows and was completely blacked out during the measurements.

The sunlight simulator was a 2 kilowatt Rank Strand tungsten halogen spotlight mounted on a balcony (Figure 6). Two lamps were used (one at a time) mounted on different balconies to simulate the different solar altitudes.

SolaLighting commissioned BRE to carry out the tests under three different sun positions. These corresponded to May 21/July 21 and 0800, 1000 and 1200 solar time (1400 and 1600 are the same as 0800 and 1000). This corresponds roughly to 0900, 1100, 1300, 1500 and 1700 BST in London (51.5° N). Table 2 shows the solar altitudes and azimuths for each measurement.

The solar azimuth is relevant for the measurement of the Solatube system which incorporates a reflector in the dome. The reflector was assumed to face exactly due south, so it was at an oblique angle to the lamp for the 0800 and 1000 (solar time) tests.

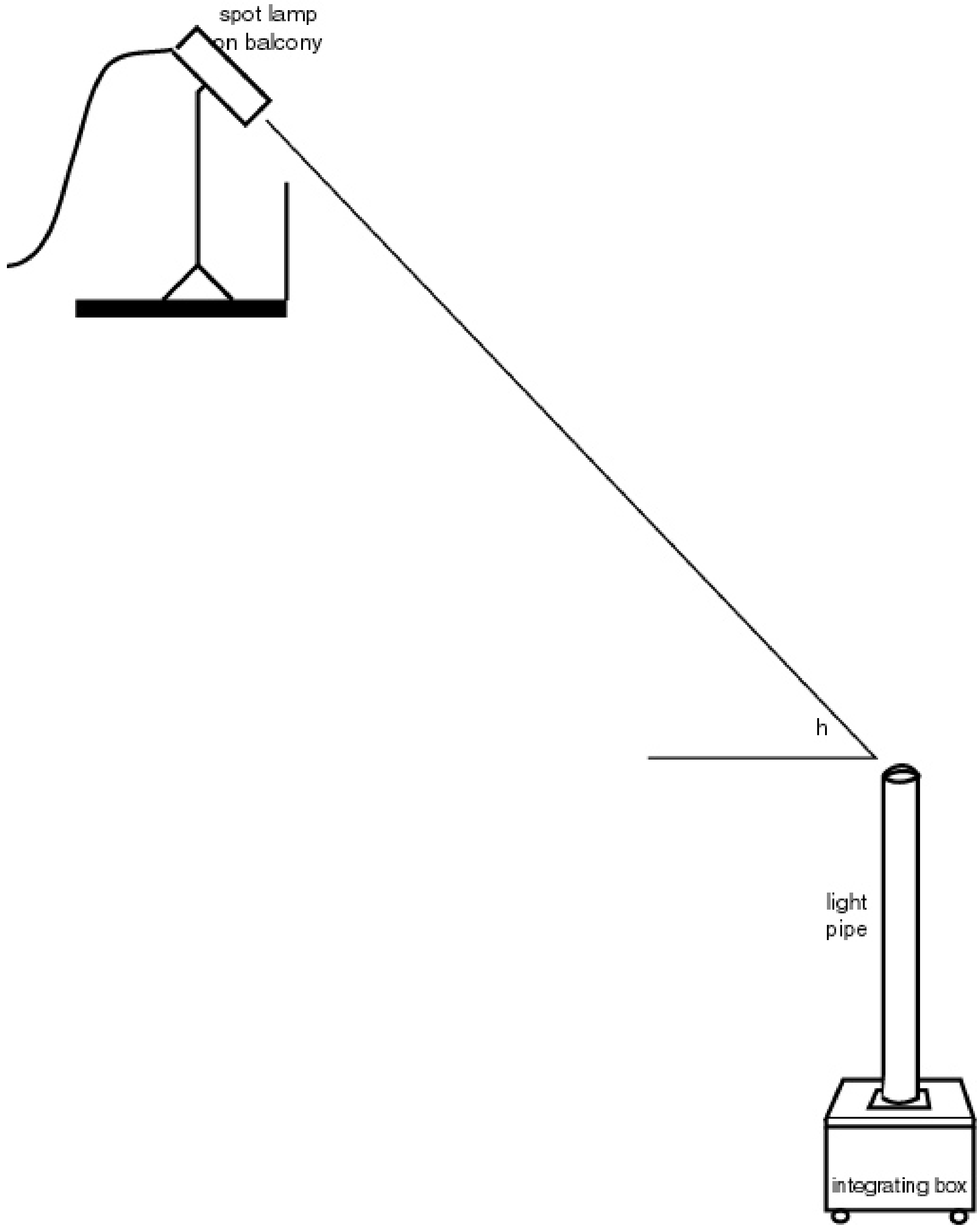

Figure 6 The spotlight, light pipe and integrating box. In each case the distance from the lamp to the top of the pipe is at least six metres.

Table 2: Solar altitudes (angle h in Figure 6) and azimuths used for the test

Time (solar time)	0800/1600	1000/1400	1200
Solar altitude degrees	33.8	50.4	58.1
solar azimuth degrees from north	101.0	132.4	180

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With the light pipes in place, the 'sun' position was adjusted using a sundial placed on top of the pipe (the dome was removed for this purpose and the top of the pipe levelled using a spirit level). This ensures that the light entering the top of the pipe is at the correct altitude and azimuth. The horizontal illuminance at the top of the pipe (ie the light entering the pipe) was measured (Figure 7).

The dome of the light pipe was then replaced, and the illuminance measured inside the integrating box.

To measure the illuminance without the pipe, the box was fitted with its aperture plate and moved back until the lamp subtended the same solar altitude (measured using the sundial). The illuminance was then measured inside the box.

The illuminance on the top of the box at the centre of the aperture plate was also measured. This is the light entering the aperture. This illuminance is significantly lower than the illuminance at the top of the pipe because the light is further away and the rays from the spotlight diverge. The difference between these two illuminances has to be corrected for.

The transmittance of the light pipe was taken as

$$T = \frac{\text{Illuminance in box with pipe}}{\text{Illuminance in box no pipe}} \times \frac{\text{Illuminance on top of integrating box aperture}}{\text{Illuminance on top of light pipe}}$$

Figure 7 Setting up the illuminance measurement on top of a light pipe under simulated sunlight.

3 Test results

3.1 Overcast sky

The results of the tests are given in Table 3.

Table 3: Light pipe transmittances under overcast conditions.

Make	Type	Diameter	Transmittance %			
			1	2	3	Average
SolaLighting	Solatube Optiview	530mm	60.6	59.1	60.2	59.9
Monodraught	Sun Pipe	530mm	49.1	49.2	51.4	49.9

3.2 Simulated sunlight tests

The results of the test are given in Table 4.

The transmittances with simulated sunlight follow a similar pattern to those under overcast skies. The overcast sky transmittance is between the sunlit transmittances for 0800 and 1000 in May.

Table 4: Light pipe transmittances under simulated sun conditions.

Make	Type	Diameter	Transmittance at given solar time %		
			0800	1000	1200
SolaLighting	Solatube Optiview	530mm	53.8	61.6	59.1
Monodraught	Sun Pipe	530mm	40.7	52.4	53.6

Appendix A – Measurement errors

A.1 Overcast sky tests

For the overcast sky tests there is one principal source of error. This is that the sky luminance distribution could depart from that of a standard overcast sky. A light pipe has its highest transmittance at the zenith, so if the zenith is brighter than expected the measured transmittance will be higher. This error was reduced by repeating the measurements. From experiences with different tests, it is estimated to be ±5%.

Obstruction caused by the greenhouse on top of the roof, the other light pipes, and trees is relatively small. It affects the measurement of light in the box without the pipe, but has no impact on the measurement with the light pipe. It is estimated that the illuminance in the box could be underestimated by 0.1%, so the measurements of transmittance could be too high by this amount.

Levelling of the pipe is an issue, but under overcast conditions even if the pipe is tilted by 2 degrees the error is less than 0.1%.

To measure transmittance accurately, the aperture plate has to be exactly the same size as the light pipe. This has been corrected for, but some residual errors may remain. A 1% error in the diameter of the aperture (5.3mm for a 530mm diameter pipe) would lead to an error of 2%.

Other errors are negligible. Light meter calibration is not an issue because the same cell is used for the measurements with and without the pipe. Screening of the box eliminates stray light.

Overall an error of ±6% is expected for these measurements. This is a relative error, so a transmission of 0.3 could be labelled 0.30 ± 0.018.

A.2 Simulated sun measurements

The measurements using simulated sunlight are subject to larger errors. These are:

1. Alignment of the 'sun' using the sundial. A 2 degree error in alignment is possible and this could give a variation in transmission of ±4%. This is roughly independent of sun altitude; misalignment is easier at higher altitudes but the effect on transmittance is less.

2. Levelling of the pipe is an issue. The top of each pipe was levelled but it is possible for the pipe to move slightly while the measurement is made. A 1 degree error here would give an error of ±3% for the lowest solar altitude and ±1.5% for the two higher ones.

3. Inside the box the illuminances measured are very low and the resolution of the meter becomes an issue. This leads to absolute errors in transmittance of ±0.01 for the lowest solar altitude and ±0.005 for the other two.

4. If the box were a perfect sphere the illuminance recorded inside it would be proportional to the light entering it regardless of angle of incidence. However at the lower solar altitude the sunlight entering the box without the pipe hits the side of the box and has a reduced effect on the illuminance recorded inside it. Because the light pipes are fitted with diffusing emitters the effect on the measurement with the pipe is smaller. This could lead to the transmittance being overestimated by around 5% for the lowest solar altitude. For the other two altitudes there might be a (smaller) underestimate.

5. Errors in the aperture plate diameter, a 2% error as before.

Other errors are smaller. Stray light reflected from the lab walls and ceiling is not significant as the spotlight is focussed on the box and the space is very large. Errors arising from the spread of the beam and the range of illuminances within it have been corrected for by measuring the illuminances at the centre of each aperture. The spotlight has a lower colour temperature than the real sun and this could lead to slight overestimation of system transmission if the pipe domes incorporate a UV filter.

Overall errors for this measurement are estimated to be ±7% ± an extra 0.01 for the lowest solar altitude (0800), and ±5% ± an extra 0.005 for the other two (1000 and 1200). So a recorded transmission factor of 0.30 for 0800 could be 0.30 ± 0.02 ± 0.01= 0.30 ± 0.03. The same factor for the 1200 measurement could be 0.30 ± 0.015 ± 0.005= 0.30 ± 0.02. For these reasons the figures in Table 4 are only quoted to two significant figures.

It should be noted that for both sets of measurements the recorded values are those for the light pipes as supplied and assembled by SolaLighting. It could be possible to assemble the pipes in a different way to give a higher or lower transmittance. However we did not observe any differences in the way the pipes were assembled and treated that would give rise to a systematic difference between their recorded transmittances.

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