

Measurement and RADIANCE Simulation of a Model Lightwell

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Abstract

A lightwell is a daylighting design to bring daylight to the lower floors in a multi-storey building. This paper presents the construction, measurement and RADIANCE simulation of a model lightwell. The model lightwell has the dimensions of 100mm (Width) * 150mm (Length) * 800mm (Height) and an outer envelope of 400mm*500mm*800mm divided into six floors. Scale-up of this model by 20:1 gives alike size of a real building. Use of matt white paint and mirror-finished surface as the lightwell wall is compared in the measurement under the overcast and sunny sky conditions. The Daylight Factor or illuminance ratio is given to assess the design of this model lightwell. The measured results are used to compare with RADIANCE simulation. The RADIANCE simulation is also used to give Daylight Factor distribution and assist the optimal design of the lightwell including the effect of the lightwell dimensions and glazing cover.

Keywords: Daylight, lightwell, measurement, simulation

1 Introduction

Daylighting is an ever important design consideration to improve building energy efficiency and create pleasant indoor environment. Electric lighting represents up to 30% of building electricity consumption in commercial and office buildings. Increasing the use of natural daylight can therefore offer significant savings in building electricity consumption¹. Using daylighting in buildings is more than providing buildings with ambient daylight and improving visual environment, it contributes greatly to human wellbeing². Use of lightwells has been a basic daylighting design strategy in multi-storey buildings to provide additional daylight supplementary to windows. Measurement of daylighting performance of a lightwell painted matt white in a model three-storey building has been reported³. Besides daylighting, lightwells may also facilitate natural ventilation to improve the thermal performance of a high-rise building⁴. Construction, measurement and simulation of a model lightwell with a reflective wall will be presented in this study.

2 Model lightwell

The lightwell in the model was 100mm (Width) * 150mm (Length) * 800mm (Height), and placed in an envelope of 400mm*500mm*800mm which was divided into six storeys. Each storey was partitioned into four equal spaces. The structure is made from plywood and hardboard, connected with wood glue and external brackets, as shown in Figure 1. Wood panels created in a 'slot' formation provided an easy-assemble structure and clean internal wall surfaces. Two sides of the lightwell were changeable to compare matt white paint and mirror finish. Other two sides of the lightwell were void to allow daylight to transmit. The opening of lightwell was covered with a diffuse glazing. Illuminance readings were taken under two weather conditions: sunny and overcast, in Nottingham, 53°N and 1.25°E. The measurement points were 22.5mm from the window void and the partition, and 10mm above

the floor due to the height of the sensor. The outdoor luminance was also noted at the same time when the internal illuminance was recorded to calculate daylight factor or illuminance ratio.

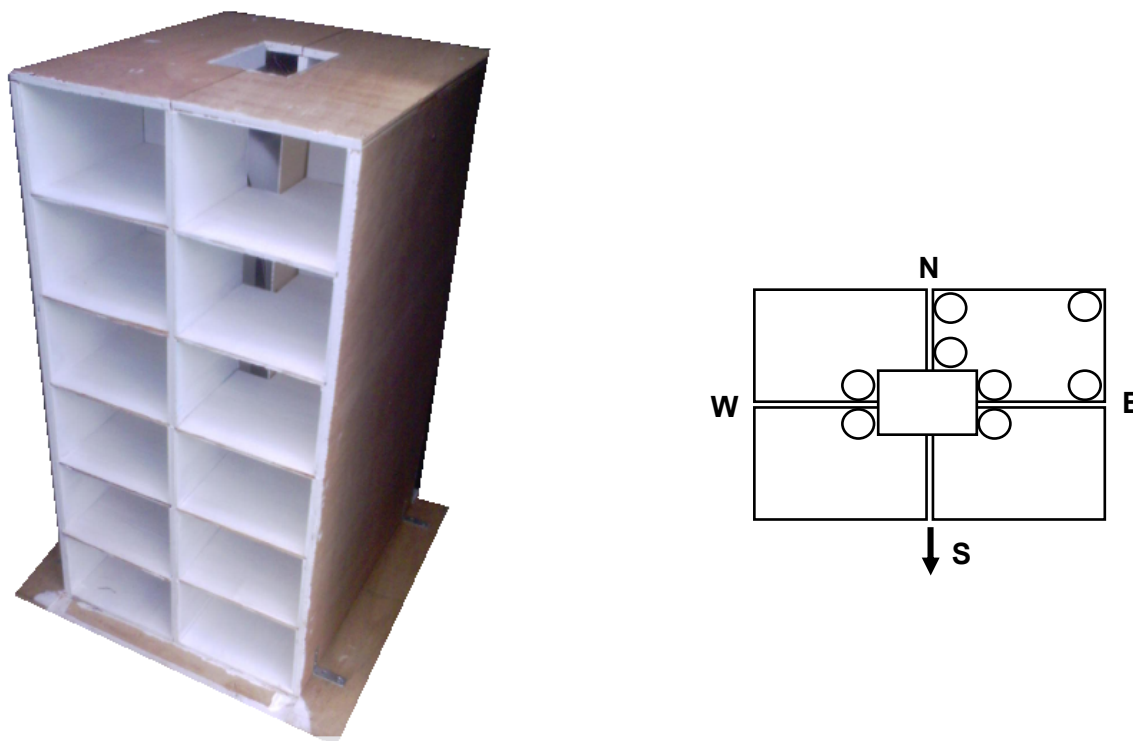


Figure 1: The model lightwell and sensor positions

RADIANCE simulation of the model lightwell was also carried out to calculate the illuminance at the same positions for comparison. It was assumed that the mirror-finished surface has a specular reflectance of 0.95, the matt white paint has a diffuse reflectance of 0.80 and the glazing cover has a transmittance of 0.9.

3 Results and discussion

The average values of the measured daylight factor or illuminance ratio are given in Figure 2. The daylight factor is an indicator of daylighting performance. An average daylight factor of 2% or less is considered to have inefficient daylight. A daylight factor of between 2% and 5% provides an ideal working environment without excessive sunlight glare⁵. The results show that for the lightwell wall painted matt white the top three floors had a daylight factor greater than 2%. The lower three floors did not receive an adequate amount of daylight as their daylight factor was lower than the recommended value of 2%. There was an increase in daylight factor across all floors when the mirror-finished lightwell wall was introduced, but the lower two floors still had a daylight factor less than 2%. For the sunny sky, the illuminance ratio was approximately a third lower than the daylight factor, however the illuminance level was much higher than the overcast condition. Figure 3 shows a comparison of the measured and simulated daylight factor or illuminance ratio for the model lightwell with a diffuse cover on the top opening. The simulated values are closer to the measured for the overcast sky than for the sunny sky. This might be caused by the assumption of a constant diffuse transmittance of the cover. The glazing cover may have a certain level specular transmission and a changing total transmittance due to its surface reflection. However, it is difficult to determine this property. Therefore, Figure 4 gives a comparison for the situation of no cover. It is obvious that there is a much better agreement between the measurement and simulation.

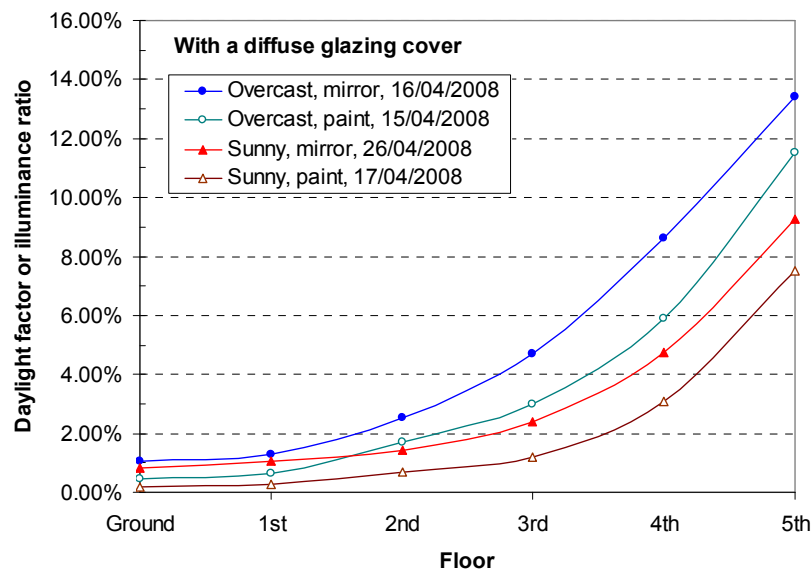


Figure 2: The average values of the measured daylight factor or illuminance ratio for differ floor

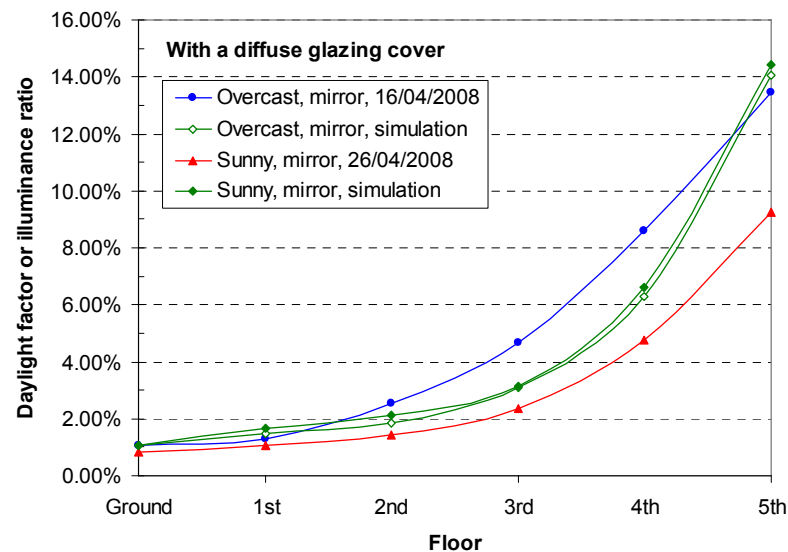


Figure 3: Comparison between the measured and the simulation

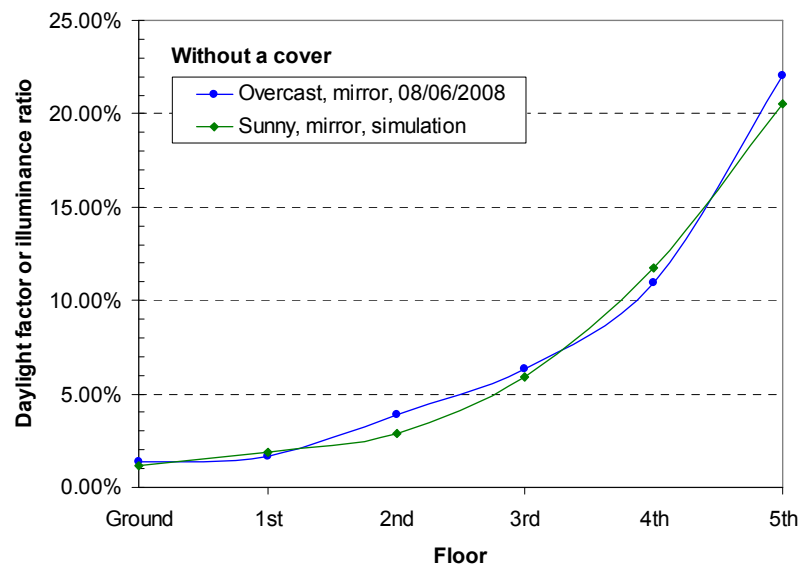


Figure 4: Comparison between the measured and the simulation

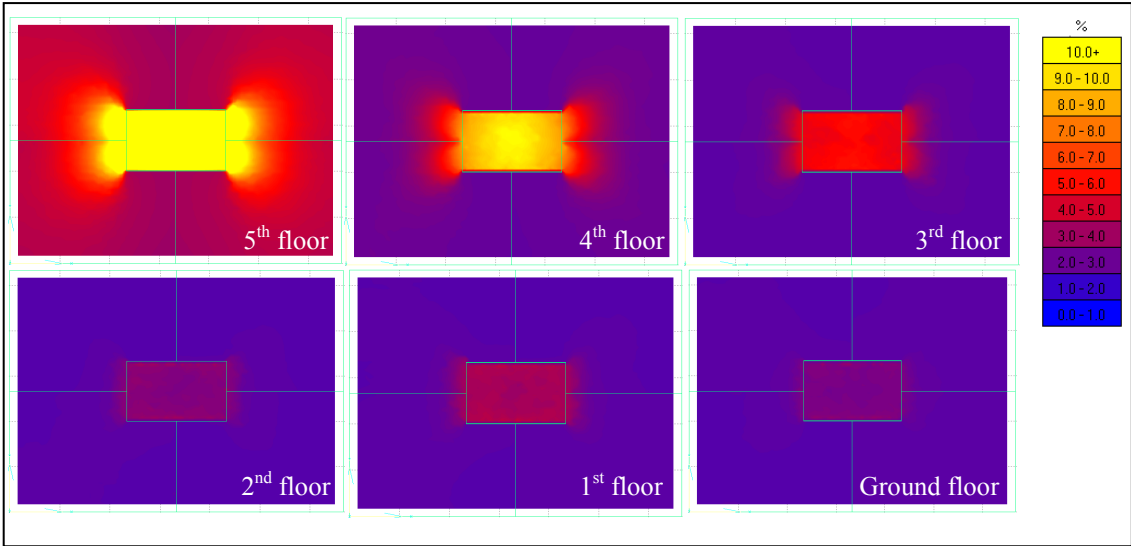


Figure 5: Simulated Daylight Factor distribution for a CIE overcast sky at 11:00am, 15/04

Figure 5 shows the simulated Daylight Factor distribution in the lightwell and its adjoining space on each floor. It is clear that the Daylight Factor in the lightwell and near the windows are much larger than the rest of spaces. As the Daylight Factor near the windows is already near or lower than the recommended 2% on the ground floor to floors 1 & 2, the current size of the lightwell is not suitable for a six-storey daylighting design. The lightwell size must be increased to illuminate the lower floor. Figure 6 shows the simulated Daylight Factor distribution on the window voids for the 25% enlarged lightwell. The Daylight Factor on the window void is more than 2% for all the floors.

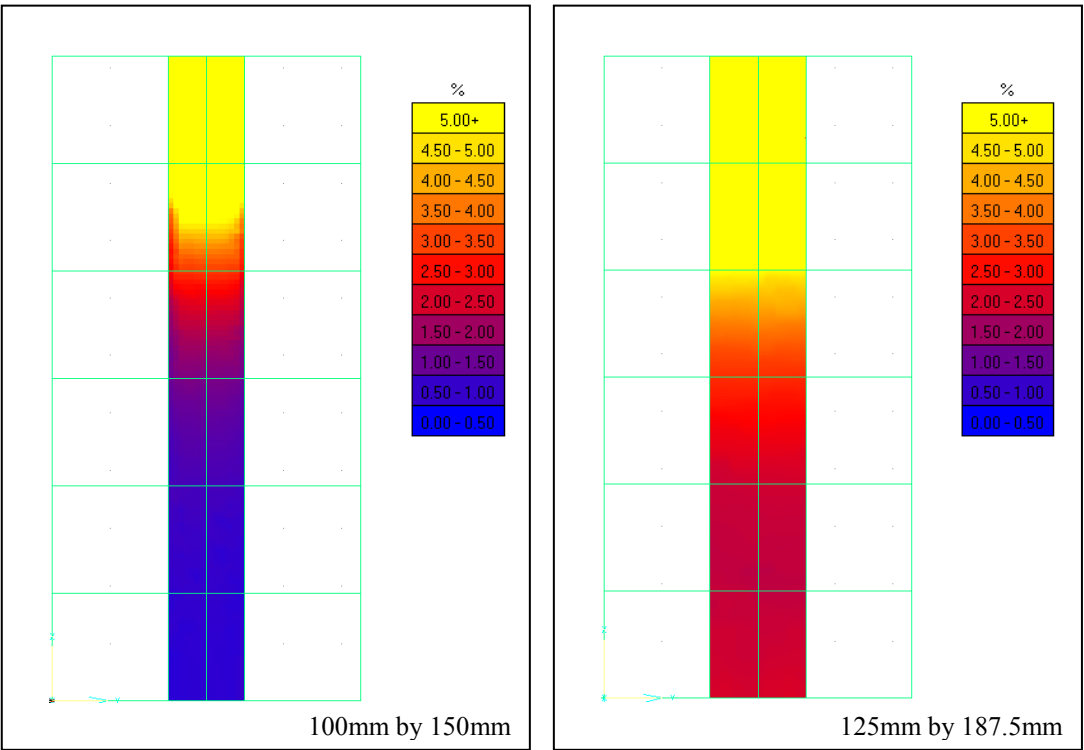


Figure 6: Comparison of the Daylight Factor distributions on the window void for the two lightwell sizes (11:00am, 15/04)

4 Conclusions

A six-storey model lightwell has been constructed and the illuminance has been measured at the selected positions near the window void for the overcast and sunny sky conditions. Compared with the matt white paint, use of the mirror-finished lightwell wall has increased the Daylight Factor by up to 100% for the lower floors (ground, 1st & 2nd) and by 30~50% for the upper floors. The current lightwell size needs to be increased by at least 25% to meet the recommended Daylight Factor of no less than 2%. RADIANCE simulation has shown a good agreement with the measurement for the situation with no cover on the lightwell top opening. But, there has been a large deviation for the situation with a diffuse cover. This might have been down to the assumption of a constant diffuse transmittance of the cover.

Acknowledgements

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References

- [¹] G. Oakley, S. B. Riffat, L. Shao. Daylight performance of lightpipes. Solar Energy, Volume 69, Issue 2, 2000, Pages 89-98.
- [²] A.A. Freewan, L. Shao, S. Riffat. Optimizing performance of the lightshelf by modifying ceiling geometry in highly luminous climates. Solar Energy, Volume 82, Issue 4, April 2008, Pages 343-353.
- [³] Z. Kristl, A. Krainer. Light wells in residential building as a complementary daylight source. Solar Energy, Volume 65, Issue 3, 1 February 1999, Pages 197-206.
- [⁴] Hisashi Kotani, Masaya Narasaki, Ryuji Sato, Toshio Yamanaka. Environmental assessment of light well in high-rise apartment building. Building and Environment, Volume 38, Issue 2, February 2003, Pages 283-289.
- [⁵] D.C. Pritchard. Lighting. Longman Group Limited, 1995.