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A novel design of a daylighting system for a classroom in rural South Africa

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Abstract

Nowadays, there exist many innovative daylighting technologies which could be used to enhance natural illumination for buildings that use more electric light during the day such as schools, industrial buildings. This study describes the passive zenithal light pipe daylighting technology's performance through the scale model method. The yield of passive zenithal light pipe was improved and was achieved by incorporating a light collimator in the light pipe. Through the design and fabrication of the light collimator, illuminance in the classroom has been improved from 178 lux distributed by commercial diffuser to 370 lux (illuminance average from 9 a.m. to 4 p.m. under sunny days from October to December 2013). A range of reflector materials were tested on the interior lining of the collimator for consistent illuminance distribution and it was discovered that rough re-used aluminum cooking foil distributed uniformly and increased illuminance. All data used has been obtained from measurements at a test location in Stellenbosch, South Africa throughout the year.

Keywords: Daylighting; Illuminance; Light collimator

1. Introduction

Use of natural daylight for interior illumination of schools doesn't only contribute to the conservation of energy and reduction of greenhouse gases emission but also enhances the performance of children in schools. In the classroom the electric light is often used during the day even though the sun is shining outside. Majority of rural schools in sub-Saharan Africa do not have access to electricity which leads to weak human and institutional capacity development. Good daylight has been shown to be closely associated with improvement in student performance and promotion of better health (Barry and Lauren, 2011). It also contributes significantly to the aesthetics and physical character of the learning space. Even if daylighting system is applicable due to the suitable climate, the majorities of schools in Sub-Sahara Africa are more than ten years old, and were not designed with daylighting as a top priority. A need exists, therefore, to find an efficient solution of improving the daylighting of existing schools (Yohannes, 2001).

The proposed solution of interior daylighting improvement for existing schools in this study is the use of passive zenithal light pipe. Passive zenithal light pipe is one of the systems capable of harvesting natural light in the interior room space. It is capable of collecting, transporting and distributing sunlight over long distances within a building (Edmonds et al., 1997). Sunlight is collected by the top dome and reflected down the tube through multiple

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Nomenclature

η_{d1}	plexiglass dome efficiency under sunny days	E_{ob}	diffuse horizontal illuminance
η_{d2}	plexiglass dome efficiency under cloudy days	E_P	internal illuminance
η_{t1}	mirrored tube efficiency under sunny days	Al	aluminum
η_{t2}	mirrored tube efficiency under cloudy days	TTE	tube transmission efficiency
E_s	direct horizontal illuminance	PZLP	passive zenithal light pipe
E_d	exterior diffuse illuminance		

specular reflections. The diffuser is fitted at the bottom end of the tube, usually to the ceiling to allow the distribution of the daylight into interior room space. Experimental results of the commercial light pipe (provided by skylite Concept Company) showed that the average illuminance level distributed interior from 9h00 to 16h00 is 178 lux on sunny days and 45 lux under cloudy days and the average illuminance level required inside the classroom by the SABS (South African Bureau of Standard) is 350 lux (for artificial lighting). This leads to the need of a light distributor device which can improve the illuminance level interior. The light collimator has been designed and fabricated with the core purpose of improving the illuminance level from 178 lux to 350 lux required in the classroom for reading and writing tasks. Experimental results of light collimator made from brushed aluminum lined interior with cooking aluminum foil (rough surface) revealed that average illuminance level reached interior was 370 lux on sunny days and 160 lux on cloudy days.

2. Experimental test analysis

2.1. Experimental test arrangement

The experiment was undertaken at the Stellenbosch University on the roof of the sun-lab between 1st April and 30th November 2013. A light pipe was installed on top of the sheet metal box of 4 m^2 surface. The test analysis of the light pipe involves the installation of the light pipe in the sheet metal, test of collection, transmission and distribution efficiency of dome, tube and diffuser respectively on sunny days and cloudy days. A commercial light pipe system used is composed of:

- Plexiglas dome of 250 mm diameter.
- A 400 mm mirrored tube of 90% specular-reflectance.
- Polycarbonate-made prismatic diffuser.

External and internal illuminances were measured using light meter (Extech light meter SDL400). Light meter measures the illuminance of an area. It displays and stores illuminance in three ranges; 2000, 20,000 and 100,000 lux from the supplied domed light sensor (see Fig. 1).

2.1.1. The dome

The efficiency of the dome (η_d) in collecting daylight was measured on sunny days and cloudy days from June to August 2013. First light meter was placed on the roof at the surface level of the dome for recording illuminance entering the dome and the second meter was placed at the top surface level of the tube for recording illuminance leaving the dome. The efficiency (η_{d1}) on sunny days was calculated as the ratio of direct horizontal illuminance E_s leaving the dome to the exterior direct illuminance entering the dome E_d. For the case of cloudy days (η_{d2}) was calculated as the ratio of diffuse horizontal illuminance

Fig. 1. Experiment equipment; light pipe, sheet metal box and light meter.