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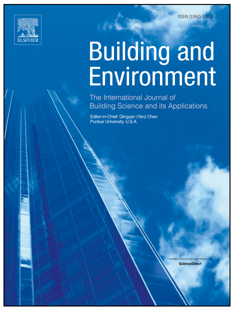

Daylight performance of a microstructured prismatic window film in deep open plan offices

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Daylight performance of a microstructured prismatic window film in deep open plan offices

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Abstract

Daylight redirecting systems with vertical windows have the potential to offset lighting energy use in deep perimeter zones. A microstructured prismatic film designed for such use was characterized using goniophotometric measurements and ray tracing simulations. The synthetically-generated bidirectional scattering distribution function (BSDF) data were shown to have good agreement with limited measured data for normal incident angles (0-60°). Measured data indicated that the prismatic film was most efficient when vertical angles of incidence were between 18-35° and within ±45° of normal incidence to the plane of the window so maximum energy savings across the full depth of the zone occurred over the equinox to winter solstice period. Annual lighting energy use and visual comfort in a deep open plan office zone were evaluated using the Radiance three-phase method in several climates and for south and east-facing window orientations. Lighting energy savings were 39-43% for a 12 m (40 ft) deep south-facing perimeter zone compared to the same zone with no lighting controls. The prismatic film with and without a diffuser controlled glare for views parallel to the window but produced glare for seated viewpoints looking toward the window. At mature market costs, the system was projected to have a simple payback of 2-6 years. Technical challenges encountered throughout the evaluation led to improvements in measurement and modeling tools and stressed the importance of having accurate input data for product development.

Keywords: Daylighting; prismatic film; microstructured film;bidirectional scattering distribution function; complex fenestration systems

1. Introduction

There has been significant research dedicated to developing micro- and macroscopic materials and systems for the purpose of redirecting sunlight and diffuse skylight deeper into the building interior. Since lighting energy use represents 13% of the total primary energy used by buildings in the United States or 5.42 quad (quadrillion = 10^{15} Btu) in 2010 (D&R International, 2012), such innovative technologies can play a significant role towards aggressive energy-efficiency and greenhouse gas emission reduction goals. Microstructured devices include angular selective coatings on glass and holographic optical elements (HOEs) (Smith and Granqvist, 2010; Sullivan et al., 1998; Papamichael et al., 1994). Static macroscopic systems for vertical windows include prismatic optical elements (POEs), mirrored louvers, lasercut panels, and enhanced light shelves (Wadsworth, 1903; Bartenbach et al., 1987; Moensch et al., 1987; Ruck et al. 2000; Andersen and Thuot, 2012; Beltrán et al., 1997; Rogers et al., 2004). Motorized solar tracking systems have also been developed for sidelighting applications (e.g., Bartenbach, 1994). More optimized and complex solutions have involved roof-mounted, sun-tracking heliostats coupled to skylights, atria and light-guiding mirrored ducts (Whitehead, 2013), or fiberoptics systems (Muhs et al., 2007). For both static

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