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A preliminary study on the performance of an awning system with a built-in light shelf

Heangwoo Lee[a], Hyang-In Jang[b], Janghoo Seo[c,*]

[a] The Graduate School of Techno Design, Kookmin University, Seoul 136-702, South Korea
[b] Institute of Green Building and New Technology Mirae Environment Plan, Seoul 01905, South Korea
[c] The Graduate School of Techno Design/School of Architecture, Kookmin University, Seoul 136-702, South Korea

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ABSTRACT

Increased energy consumption is an ongoing research concern worldwide. In particular, uses of ongoing studies are focusing on improving indoor comfort via the development of double-skin facades that combine various skin element technologies. In light of this, this study aims to develop an awning system with a built-in light shelf, which is a new type of system combining an awning and a light shelf. It also confirms the effectiveness of this system based on a full-scale test bed by deriving the energy reduction performance and improvements in the comfort of the indoor lighting. The awning system proposed in this study has a built-in light shelf below the awning, and there is a cut-out hole in the cover of the awning so that natural light can hit the shelf. As a result, the system successfully prevents an increase in the indoor temperature by blocking the incoming sunlight and introduces natural light deep within the interior, improving the light uniformity and reducing the lighting energy consumption. The effectiveness of the system was demonstrated by analyzing the improvement in the indoor illumination uniformity and the cooling and lighting energy savings provided by the proposed system compared with existing awning and light shelf systems.

1. Introduction

According to the Buildings Energy Data Book published by the US Department of Energy in 2011, lighting and air conditioning account for 9% and 10%, respectively, of total energy consumption in the building sector [1]. Various studies and technical developments are being pursued on an ongoing basis with the aim of reducing energy consumption due to lighting and air conditioning in the building sector [2,3]. Simultaneously, as there is growing interest in improving quality of life, more studies are being conducted on how indoor energy savings and improvements to indoor comfort can be achieved [4,5]. From the perspective of building energy savings and improvements in indoor lighting environment, various studies have been conducted on how the development of a double-skin façade that combines various skin element technologies can maximize both energy savings in the building sector and the comfort of indoor spaces [6–8]. We believe that there is a growing need for such studies.

Awnings, which fall under the category of skin elements, are shading systems that are installed on the main entrances or windows of a building. They are used to adjust the amount of natural light that reaches indoor spaces by blocking incoming solar radiation with a shading panel. Such systems primarily block direct sunlight, which thereby reduces the cooling load of indoor spaces during summer while reducing glare and improving the indoor lighting environment. However, the installation of the awning might increase the amount of lighting energy as the amount of incoming natural light declines. On the other hand, the light-shelf system, which is a natural-light system, introduces outside natural light into the indoors by reflecting the light, and it is therefore beneficial in terms of lighting energy consumption. From this perspective, an appropriate combination of the awning and light shelf is better than conventional awning systems in terms of the cooling energy during summer, the indoor lighting environment, and the total lighting energy. It can maximize the building energy savings while achieving a comfortable indoor lighting environment.

In this study, an awning system with a built-in light shelf is proposed, its effectiveness was confirmed by conducting a performance evaluation based on energy savings in lighting during summer, and the comfort level related to the indoor lighting environment was assessed.

* Corresponding author.
E-mail address: seojh@kookmin.ac.kr (J. Seo).

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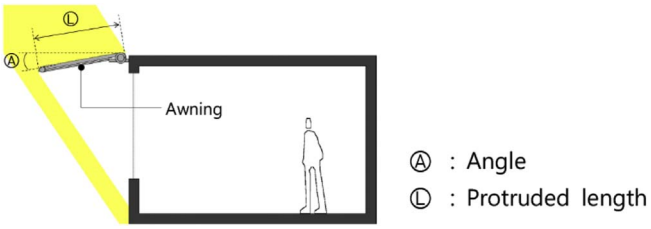

Fig. 1. Schematic of an awning and its associated variables.

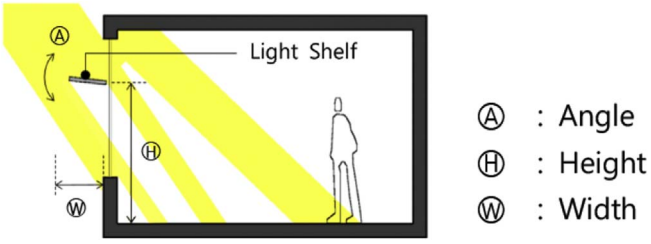

Fig. 2. Schematic of an adjustable light shelf and its associated variables.

Table 1
Recommended standards for indoor illumination intensity and temperature.

Recommended standards for indoor illumination intensity (lx)				
Standard	Task grade	Minimum allowed illumination	Standard allowed illumination	Maximum allowed illumination
IES (USA)	General	500	750	1000
JIS Z 9110 (Japan)		300	500	600
KS A 3011 (Republic of Korea)		300	400	600

Recommended standards for indoor temperature (°C)	
Standard	Summer
ANSI/ASHRAE Standard 55–1992 (USA)	23.0–26.0
ISO Standard (Europe)	23.0–26.0

1.1. Awnings and their associated variables

Awnings are shading systems that are frequently attached to the exterior of low-rise commercial buildings. An awning is installed at the main entrance or window of a building to control the amount of natural light that reaches the indoor spaces and to prevent both glare and a rise in indoor temperatures. Awnings generally protrude from the wall of a building and their lengths can be extended from 1.0 to 3.5 m according to either the specifications of the manufactured product or the size of the window or building entrance, as shown in Fig. 1 [9]. Furthermore, awnings are generally angled away from buildings (at an angle of between 5° and 45° from the horizontal) to prevent the pooling of rainwater in the event of a sudden storm [10].

1.2. Light shelves and their associated variables

Light shelves are natural lighting systems that reflect natural light from the exterior deep into indoor spaces, as shown in Fig. 2, and are an efficient means of saving lighting energy. Light shelves vary depending on their height, width, angle, and reflectivity, which can all be adjusted to improve the lighting performance of light shelves in response to external environmental factors such as solar altitude.

1.3. Recommended indoor illumination and temperature standards

In this study, the illumination and temperature standards for indoor spaces in the US, Europe, and Korea were considered when conducting a performance evaluation of an awning system with a built-in light shelf, as shown in Table 1 [11–15]. The standard illumination intensity for the appropriate illumination and lighting control of indoor spaces was set at 500 lx. Furthermore, 26 °C was chosen as the recommended standard temperature for indoor spaces in summer.

2. Methods

2.1. Proposed awning system with built-in light shelf

This study addresses the issue of increased indoor lighting energy, which is often displayed in awning systems, for different combinations of light shelves and awnings. It is likely that this solution can also result in the decrease of building energy usage while improving the indoor lighting environment. This study proposes the form and control variables of the proposed awning system with a built-in light shelf as follows.

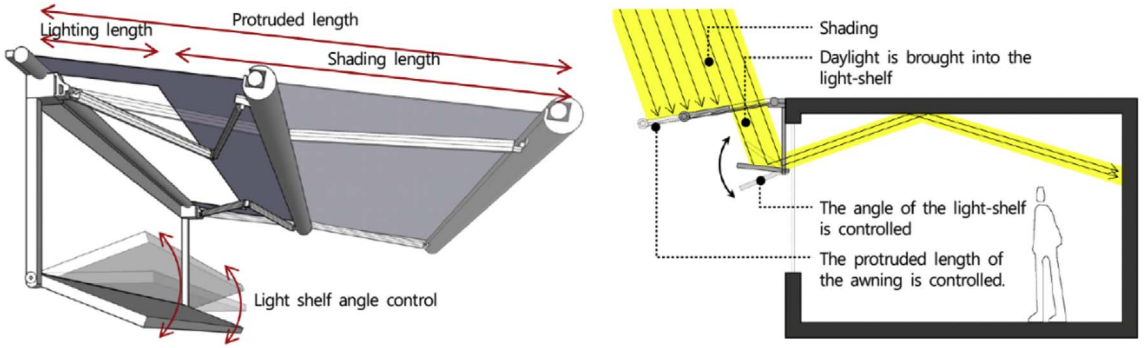

Fig. 3. Schematic of the awning system with a built-in light shelf (left) and the entry of light into the room (right).