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Development of a wall module employing aircap layers

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ABSTRACT

Various technologies are under development to meet the increasing requirements of energy-efficient buildings. An especially high demand exists for research into building facades, which are known to have the highest levels of heat loss compared with other building components. To mitigate this heat loss, Aircaps^{TM} (hereafter "aircaps") have gained attention because of their insulating performance and low cost. However, because of durability issues, research into aircaps has been limited to their attachment to windows to enhance the insulating performance of building facades. In this study, an aircap module with enhanced layering and durability was developed, and the system's energy reduction performance was evaluated using a real-scale testbed. The following conclusions were drawn: 1) An aircap wall module equipped with frames and polycarbonate layers for greater aircap durability was achieved; 2) Due to its transmissivity, the aircap wall module was capable of lowering lighting energy needs more than other insulators, such as sandwich panels; 3) Aircap wall modules with thicknesses greater than 15 cm reduced the heating and cooling energy consumption more than 5-cm sandwich panels; 4) 10-cm aircap wall modules resulted in electricity consumption lower than 5-cm sandwich panels for lighting, cooling, and heating during both the summer and winter seasons. On account of low altitudes and aircap transmissivity, 5-cm aircap wall modules reduced building energy needs more than 5-cm sandwich panels during the winter season.

1. Introduction

Sudden shortages in energy resources have sparked worldwide attention to increases in energy consumption and have raised the need for global resolution of the problem [1]. According to the "Annual Energy Outlook 2015″ published by the Energy Information Administration, energy consumption for buildings, transportation, and industry was 47.6%, 28.1%, and 24.4%, respectively, of which building energy consumption was the highest [2]. Increases in building energy consumption are mainly associated with building facades, which are known to have the highest levels of heat loss compared with other building components [3,4]. Therefore, research to enhance the performance of building facades has been mainly conducted with the aim of developing phase-change materials (PCM), double-skin facades, and energy-efficient windows. These studies involved the improvement of indoor heating comfort levels when applying phase-change materials [5], the improvement of building envelope thermal performance through phase-change materials [6–9], the development of double-skin façade control technologies [10,11], the design and application technologies of double-skin facades [12,13], and the development of design and control technologies of windows [14,15]. Such studies realized both a reduction of energy consumption in buildings and an improvement in indoor comfort levels by combining advanced technologies. Although such developments have improved the thermal insulation performance of building facades, they are considered limited because they entail high building costs, rendering them uneconomical [16,17].

The material used in the aircap wall module proposed in this study is a product developed by the Sealed Air Corporation of the United States [18]. The aircap material comprises a layer of air pockets, which is sealed between two sheets of the polyethylene film. Aircaps have been predominantly used as a buffer material for packaging purposes. However, considering the insulating properties of aircaps, they have recently been applied as an insulation material for use in both hot and cold weather. Despite the low cost and outstanding insulating performance of aircaps, research into their use as an insulation material has been limited because of issues with their durability. The existing research has typically focused on the application of aircaps as an insulation performance enhancer

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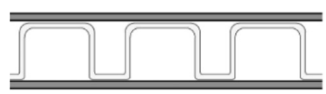
Table 1
The purpose and use of aircaps according to previous studies.

Author	Research goal	Use of aircaps
Lee et al. (2015) [19]	Performance evaluation of varying locations of aircap attachments to windows	Improvement of window insulating performance by attaching aircaps to windows
Je et al. (2015) [20]	Development of appropriate aircap specifications for the improvement of window insulating performance by application of aircaps having various specifications	
Lee et al. (2017) [21]	Development and performance evaluation of aircap modules capable of attachment and detachment to windows	

Table 2
The structure and purpose of aircaps according to type.

Type of aircap	Image	Cross section	Purpose
Single-layer aircap			Packaging
Double-layer aircap			Thermal insulation

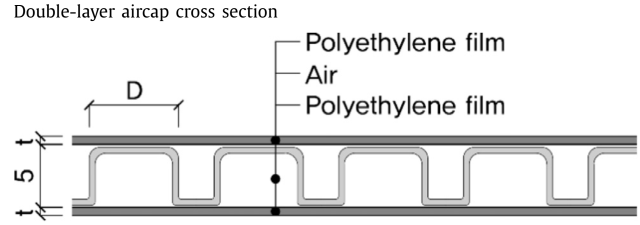
by attaching them to windows rather than as an independent thermal insulator [19–21]. In addition, owing to the high optical transmission of aircaps, layering them allows the thermal performance of the material to be adjusted without significantly reducing the overall light transmission. This feature also introduces the possibility of applying aircaps as a material for new building facade concepts in which energy for lighting purposes can be saved.

In this study, after resolving the durability and layering issues associated with aircaps, a new type of aircap wall module for use in building facades is proposed. Real-scale test bed activities were conducted to compare the energy-saving performance of the developed module with that of sandwich panels in terms of the energy consumption levels for lighting, heating, and cooling. These tests were performed to validate the developed aircap wall module and establish a set of basic research data.

Table 3
Double-layer aircap specifications.

Type	D (Diameter of air layer)	t (Thickness of coating layer)
1	10 mm	0.2 mm
2		0.4 mm
3	20 mm	0.6 mm
4	25 mm	
5	30 mm	

Double-layer aircap cross section



*The thickness of the aircap is determined by the thickness of the two polyethylene sheets. The thickness of the layer of air between the two polyethylene sheets is 5 mm.

1.1. Previous research on aircaps and their specifications

"Aircap" refers to a material in which air pockets are trapped between two sheets of polyethylene film. On account of their physical features, aircaps have both buffering and insulating properties. However, because of the low durability associated with the vinyl materials used in aircaps (see Table 1), past research on them has been limited. Research has largely centered on the application of aircaps to enhance insulating performance by attaching them to windows rather than on their utility as an independent insulator. By contrast, the present research differs in that a new concept for a building facade material employing an enhanced type of aircap with improved durability was developed and validated.

As shown in Table 2, double-layer aircaps are used as insulating sheets, whereas single-layer aircaps are used for general packaging purposes. Despite the various existing specifications for double-layer aircaps (shown in Table 3) [22], the performance evaluations in this study were undertaken using only Type 2, 10-mm circular air pocket aircaps, based on past aircap research [21].

1.2. Appropriate levels of indoor illumination and temperature

To evaluate the performance of the aircap module while maintaining appropriate levels of indoor illumination and temperature, the electrical consumption of lighting, heating, and cooling devices was calculated. The standards selected for these levels are important indices that are used when conducting performance evaluations. As shown in Table 4, the standards for appropriate levels across various countries were observed. An illumination level of 500 lx was established as appropriate level of indoor illumination for the purposes of conducting the performance evaluation. In addition, the appropriate levels of indoor temperature were established as 26 °C and 20 °C for the summer and winter seasons, respectively.