# Cooling load reduction effect in slim double skin facade (SDSF)

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# Cooling load reduction effect in slim double skin facade (SDSF)

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**Abstract**. The office building consumes cooling energy in the summer season. Building envelope such as different windows affects the indoor heat gain. Operation of the cavity in double skin façade (DSF) is widely used passive design and can reduce the cooling load. Many cases have applied a building envelope. However, increase the initial investments affect the interruption of the application of the DSF. Hence, this paper investigated the slim double skin façade (SDSF) for cooling load reduction effect of the ventilation cavity. Heat balance analysis was conducted using EnergyPlus to investigate a heat transfer mechanism for SDSF. Finally, based on the analysis, SDSF can significantly reduce the cooling load in the office building in the lower cost than other DSF types.

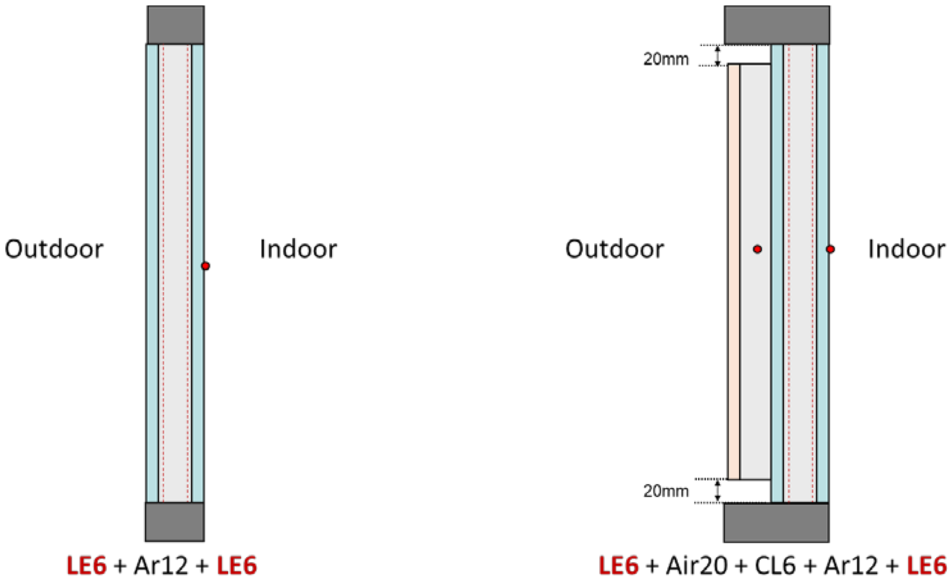
## 1. Introduction

The energy consumption in buildings is one of the significant sources of energy. Building design should consider the passive design to minimize the load and energy consumptions. Korea Government engaged a regulation for energy reduction in the building sector. This regulation aims that all the buildings will be zero-energy buildings by 2025. By regulations, windows applied newly buildings need to certification for the first-grade energy efficiency rating. However, cooling energy consumption has increased rapidly in Korea because of hot and humid weather with further global warming and modern building design applied transparent envelope without difficulty. This phenomenon needs to modification with a passive design such as building envelope. For the past, double skin façade (DSF) has become in building design to innovate both design and energy saving by natural ventilation strategy, cooling load, and lighting in non-residential buildings.

Many researchers investigated the energy performance of DSF based on energy simulation tools such as EnergyPlus, ESP-r, TRANSYS, and DesignBuilder). They claimed that the DSF could reduce energy consumptions[1-3]. Park et al. investigated the validation and developing the simulation model for DSF systems[4-6]. Lee et al. analysis the cooling reduction effect DSF with Venetian blind operation[2]. Aleksandar et al. examined multi-story naturally ventilated DSF[7]. Alexandra et al. studied the DSF with buoyancy-driven airflow using computational fluid dynamics (CFD) simulation. Although DSF has significant strength in building energy, initial cost and additional occupied spaces in the cavity are significant obstacles for application of DSF. Due to the obstacles, we designed slim double skin façade (SDSF) in the office buildings. SDSF can overcome the higher initial cost and reduce cooling energy consumption.

The objective of this study is to analysis the cooling load reduction effect of SDSF in summers seasons. We conducted measurement in test chamber applied the SDSF in summer seasons. The test results were validated by comparing the energy simulation (EnergyPlus). Also, this study applied the energy management system (EMS) operation to the cavity in SDSF for saving heating load in the cold seasons.

Figure 1 The facility for test chambers




**a)** **b)**

Figure 2 Schematic diagram widows and measurement points a) double glass, and b) SDSF

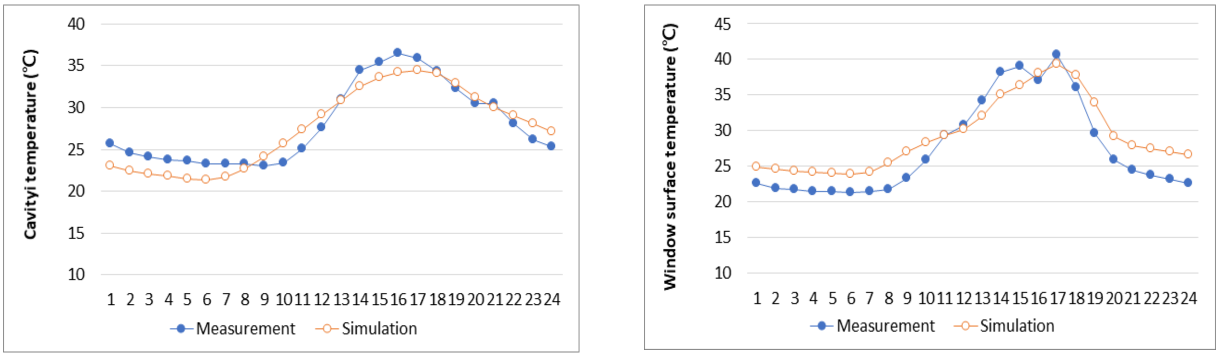
## 2. Validation of the energy simulation by comparison with measurement data

*2.1 Description of the test chamber SDSF*

We investigated the field measurements in August 2016. The test chamber was in Yongin, Gyeonggi – do. Dimension of test chamber is: width = 2.8m, depth = 4.6m, and height = 2.3m. The chamber was controlled at 24 ℃. The experiment was conducted in two chamber rooms. One had a double glass window, and another had SDSF (Figure 1). SDSF and double glass window was 2.9m x 2.3m.

Conventional DSF can reduce total building load when reasonable operating. However, the initial cost in building construction and reducing indoor spaces by the cavity in DSF is significant obstacles to the application of DSF. SDSF has double skim façade with the slim cavity. SDSF can reduce initial cost and reduce the total cooling load. SDSF has different ventilation control strategies because of the slim cavity.

SDSF consist of clear single glass (6mm) + 20mm cavity (open, ventilated by 20mm cavity) + 6mm low-e glass + 12mm argon + 6mm low-e glass (Figure 2). U-value in SDSF is 1.38W/m$^2$·K, and SHGC is 0.50 based on the certificated test. Table 1 summarized boundary conditions of reference building.




a) Cavity temperature b) Window surface temperature

Figure 3 Validation of window temperature

Table 1 Summary of reference building

| Category | Sub category | Value |
|---|---|---|
| Building information | | Yongin, Gyeonggi – do<br>Office |
| Scale | Floor area (m$^2$) | 10 |
| | Ceiling height (m) | 2.3 |
| Wall U-value | External wall (W/m$^2$K) | 0.54 |
| Window (SDSF) | U-value (W/m$^2$K) | 1.38 |
| | SHGC | 0.5 |
| Window (Double-Glazing) | U-value (W/m$^2$K) | 1.8 |
| | SHGC | 0.4 |
| Internal heat gain | People (people/m$^2$) | 5.7 |
| | Lighting (W/m$^2$) | 4.7 |
| | Equipment (W/m$^2$) | 5.9 |
| Air-tightness | Infiltration (ACH) | 0.3 |
| Set point temperature | Cooling (◦C) | 20 |

*2. 2 Simulation method and validation*

EnergyPlus was used for simulations. EnergyPlus is a building energy simulation program. Many researchers have used the EnergyPlus for the DSF. We focused on the heat balance method of the effect of the SDSF and glass cavity.

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EnergyPlus object "zoneVentilation:Wind and-stackOpenArea" was applied to the simulation model. This model can simulate the ventilation in the cavity as cavity size, inlet speed (wind), cavity height and temperature difference. The simulation was investigated from June to September for cooling load reduction.

The air exchange rate in the cavity is one of the important factors to evaluate the cooling load. We investigated the inlet velocity at the cavity. The inlet velocity was various due to the outdoor conditions. So, we used the average measurement data as 0.26ACH.

Internal heat gain data has similar conditions between measurement and simulation. The average lighting and equipment were 4.7 W/m$^2$ and 5.9 W/m$^2$, respectively. Infiltrations were assumed the 0.5ACH which was regulation of minimum air exchange rates in the buildings. The schedule and density of the occupants, lighting, and the equipment were based on ASHRAE Standard 90.2 in this study (ASHRAE 2007).

To apply the simulation model for SDSF, we validated the simulation model with measurement data. Under validation, cavity temperature tends to the same pattern. The peak temperature is around 36℃ at 4 p.m and decreased slowly (Figure 3-a). There was little temperature difference in window surface temperature (Figure 3-b). We assumed that the sensitivity of simulation is higher than measurement due to maintaining the indoor temperature and heat transfer in the cavity. The average temperature difference is 1.5℃; peak time is 5 p.m. However, the difference with two data was assumed the negligible difference.

We analyzed the impact on the reducing cooling load by the cavity. So, not all HVAC systems were modeled in this study. The cooling load was calculated using EnergyPlus function "idealLoadsAirSystem." This function can calculate the cooling and heating load for not exceed air capacity.

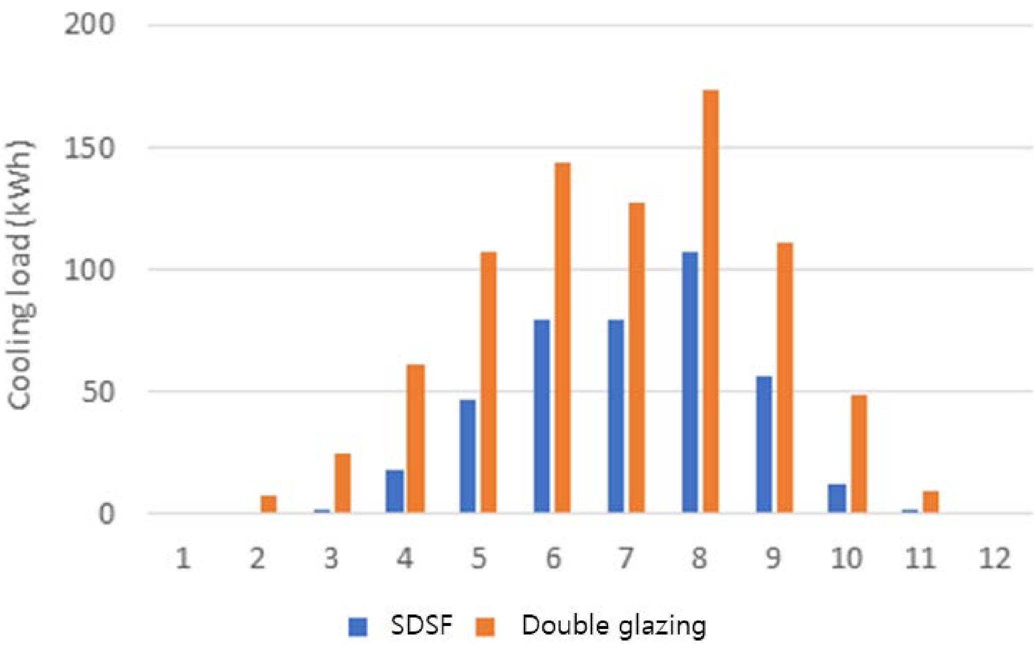


Figure 4 Cooling load in summer seasons

## 3. Simulation result

### *3. 1 The cooling load reduction effect*

In this study, we analyzed the cooling load reduction effect about SDSF by using EnergyPlus. The EnergyPlus was used for simulations. Figure 4 presents the monthly cooling load in two cases. The cooling load was from Feb. to Nov. The internal heat gain, and solar gain makes the cooling load in the zone. Cooling load increased the daily time increased outdoor air temperature. The cavity in SDSF has a cooling effect by ventilation. This phenomenon reduces surface temperature.

Total cooling load in double glazing showed 816kWh. Comparison of the total cooling load, cooling load in SDSF, showed 401kWh. Ventilation cavity can reduce the total cooling load of 50.1%. From June to Aug, total cooling load decreased by 57.6% by ventilating the cavity. Only one side is faced with outdoor conditions in the test chamber. Glazing ratio of the test chamber is higher than 0.9. Only one side is faced with outdoor conditions. Therefore, it so clarifies the effect on the total cooling load reduction by SDSF with ventilation in summer seasons.

### *3.2 Operation of the cavity*

In the intermediate season (3-5, 9-11), the heating and cooling load capacity were showed considerably. EMS used in this paper to reduce to heating load in the intermediate season. Ventilating the cavity affects the heating and cooling load because the outdoor temperature widely fluctuated in the occupied period. So, the application of EMS will control the open cavity by outdoor temperature to reduce the useless heat loss through ventilation.

Figure 5 shows the additional heat loss through ventilation in the cavity and shows the relationship between outdoor temperature and heat loss. When opening the cavity, additional heat loss appears between cavity space and indoor space. By the simulation, the outdoor temperature was under the 20 ℃; additional heat loss appeared. So, We had set-up the open temperature in 20℃. As a result, SDSF with the operation of EMS, the total heating load reduced the 9.9%.

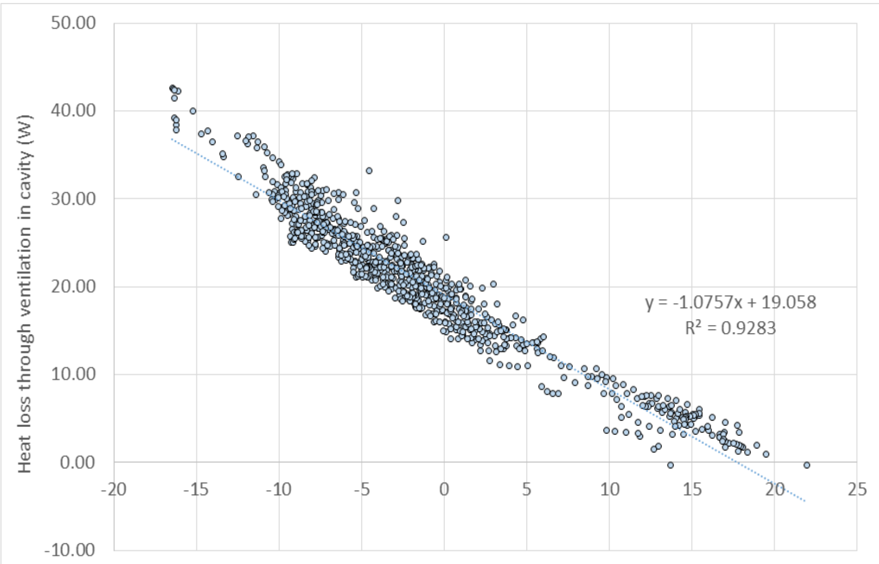


Figure 5 Additional heat loss through ventilation in the cavity

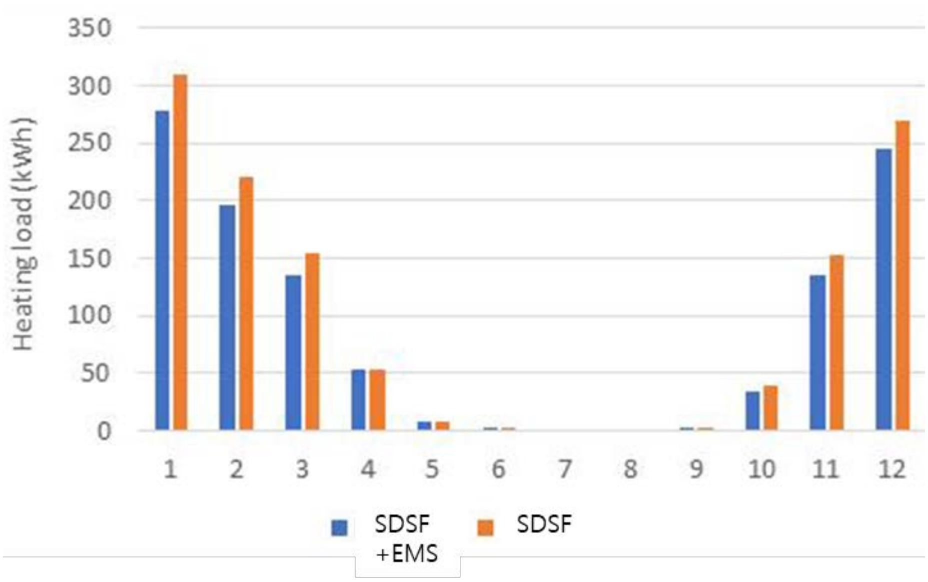


Figure 6 Healing load in SDSF and with EMS

## 4. Conclusion

In this study, we investigated the energy reduction effect of the SDSF and EMS used energy simulation. This study conducted the validation between simulation and measurement for SDSF.

This analysis demonstrates the cooling reduction effect by ventilated SDSF. The total cooling reduction was 50.1% and 57.1% in the summer seasons (6-8). Additionally, we applied the EMS to SDSF to reduce the additional heat loss in the intermediate season (3-5, 9-11). EMS can reduce the heating load of 9.9% in the test chamber.

This investigation has some limitations in analyzing the simulation in details for SDSF and cavity space. However, SDSF system is one of the alternative passive design for reducing the cooling load in hot and humid in non-residential buildings.

This analysis needs to be conducting the SDSF for retrofit or new buildings. To investigation of the energy consumption in detail, long-term field measurement will be necessary to study the load reduction of SDSF in cooling and heating seasons in the future.

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