MEASURES OF SET-BACK CONTROL IN ACCORDANCE WITH THE HEAT STORAGE FUNCTIONS OF OFFICE BUILDINGS

[1]JUN HONG, [2]HYE-JIN KIM, [3]HYE-WON KIM, [4]YU-SUN AHN, [5]BYUNGSEON SEAN KIM

Department of Architectural Engineering, Yonsei University, Seoul, Korea
E-mail: [1]hongjun84@hanmail.net, [2]threestar330@daum.net, [3]hyewon_9398@naver.com, [4]ahnew1@naver.com, [5]sean@yonsei.ac.kr

Abstract - Setback control is an HVAC control method to conserve energy in heating or air conditioning. Peak shaving through night setback control during winter months when heating is used not only affects energy conservation in a building but also the energy supply infrastructure. In order to apply appropriate setback control, affecting factors according to the characteristics of the building must be taken into account. As such, this study presents an optimal setback control method according to the heat storage function of office buildings. A test of the function of the suggested setback control was conducted using EnergyPlus, an energy analysis program. For the analysis model, a small office among the DOE reference model was used. Depending on the control method, they were categorized into no setback model, typical setback model, and set temperature reset model. The thermal mass in each model changed depending on the location of the thermal insulating material of the structure. For the set temperature reset model, a separate set-back operation time was set. The analysis results show that the thermal mass, in accordance with the location of the thermal insulation material, is a factor affecting the zone air temperature. The suggested model, when compared to the typical setback model, had a smaller peak load and monthly energy usage, and called for a different control method depending on the heat capacity.

Index Terms - Thermal mass, Set-back, Control, Peak shaving

I. INTRODUCTION

According to the 5th assessment report by the Intergovernmental Panel on Climate Change (IPCC), global warming caused by greenhouse gases (GHG) will continue [1]. Concerns over the strict regulations of emissions and climate change have led to the emergency of new technologies and methods [2]. Among them, the building sector that account for 35% of total worldwide energy consumption, is a critical element that must be taken into account [1].

In Korea, approximately 22.3% of total energy consumption occurs in residential and commercial categories [3]. In particular, energy consumption of commercial or public service buildings account for 9.5%, and energy consumption for heating or air conditioning take up a high share of 56.7% of total energy consumption [4]. While studies have been conducted on the various control methods to reduce energy consumption in buildings, more than approximately 39% of energy consumed in the HVAC system is being reported as wasted energy due to inefficient system operation during unoccupied periods [5]. This is the result of operations that do not take into account the characteristics of each building, and thus calls for appropriate control through clear analysis of buildings.

Set-back control is a control measure to reduce energy consumption and peak shaving through appropriate heating or air conditioning during unoccupied periods in the day time or night time [3]. According to preceding studies, when set-back control is applied, 28.2% of heating energy and 9.5% of air conditioning energy in cold climates, and 53.0% of heating energy and 16.9% of air conditioning energy in a hot and humid climate can be saved [6] – [7].

Many preceding studies have been carried out on measures to conserve energy using set-back control. However, most of them analyzed the amount of energy saved during the setback period or due to changes in set temperature in residential buildings. While it is clear that energy is conserved using this method, studies on control methods that take into account the characteristics of the building are still lacking. As such, this study sought to identify set-back control measures in accordance with heat storage functions of office buildings in the winter.

II. METHOD AND SCOPE

This study was analyzed using a simulation. The energy analysis tool for buildings, EnergyPlus was used. Independent variables were thermal mass, set temperature, and control time, while the output analyzed was zone air temperature, surface temperature, and zone heating rate.
The study was conducted in the following order.

- Analysis of non-heated, non-air conditioned status to analyze the thermal characteristics of a building.
- Analysis of heat storage functions of buildings through no set-back.
- Comparison of control functions taking into account typical control and heat storage functions.

III. SIMULATION

A. Description

The simulation test model was a small office among the DOE-reference models. Figure 1 shows the exterior of the test model, and Table 1 shows the characteristics. The test model is a flat-roof, one story building in a simple rectangular shape. In this simulation, the roof and floor

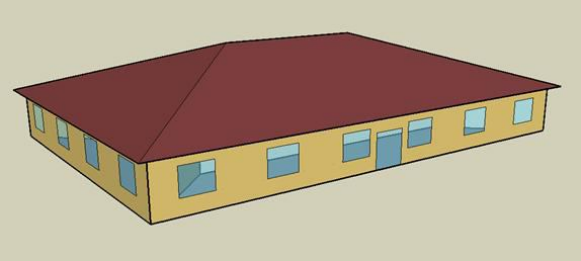


Fig 1: Test Model

Table 1. Simulation Model Overview

Building Description	
Data Source	2003 CBECS, ASHRAE Small Office 30% Advanced Energy Design Guide
Principal Building Activity	Office
Total Floor Area	511㎡
Number of Floors	1
Floor to Ceiling Height	3.1m
Construction Type (External Wall)	Mass wall
Construction Type (Roof)	Attic
Foundation Type	Mass Floor
HVAC	Ideal Load
Infiltration Rate	1 ACH
Weather Data	TMY2 data for Seoul, South Korea latitude: 37.56_N, longitude: 126.98_E

were considered to be adiabatic, and thus the solar heat gain of the flat roof was not taken into account. Analysis was conducted during the winter season (i.e. January) and the weather data for Seoul, Korea, were used.

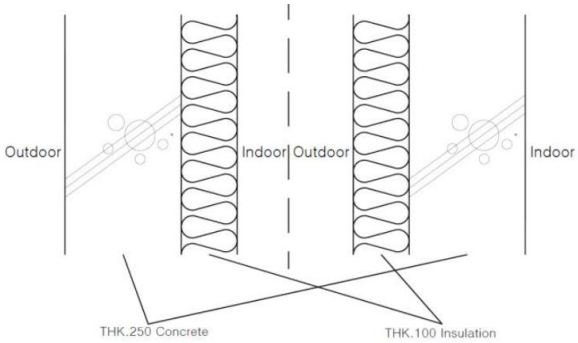


Fig 2: Exterior Wall Types

B. Simulation Case

The simulation case used for analysis can be categorized into two types of case as seen in Figure 2, depending on the location of the insulating material. The structure according to the thermal insulating material was considered to be a thermal mass in the zone analyzed. Cases according to the control method were categorized into three: no set-back, typical set-back, and set temperature reset.

III. ANALYSIS

A. In a condition of no air conditioning

To verify the thermal characteristics of the building, the zone air temperature was analyzed without control.

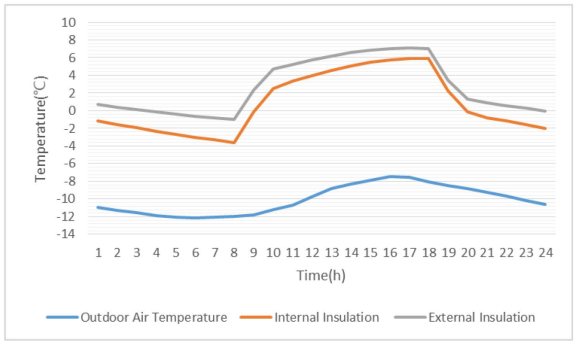


Fig 3: Temperature Changes according to the location of the thermal insulation

Figure 3 is a chart that shows the temperature changes according to the location of the thermal insulating material. In both cases, there was a pattern similar to the temperature changes in the external air. The case where the thermal insulating material was in contact with external air had a relatively higher temperature.

B. Comparison of typical control and set temperature reset

For typical control, the temperature was set for night time when it was unoccupied, at 15.6 degrees. As seen in Figure 4, the heating rate during night time was relatively lower in the case with thermal mass.

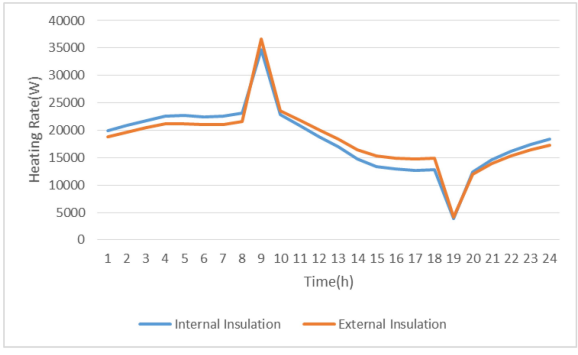


Fig 4: Heating Rate during Night Time

In contrast, the peak load was relatively higher in the case with the thermal mass. The set temperature reset has two variables. The first is the change in night time set temperature by ±1 degrees from the basis point of

15.6 degrees. The second is the point where the temperature starts to rise for peak shaving. In the case without thermal mass, when the set-point temperature was controlled to be 14.6 degrees at 06:00, 17.6 degrees at 08:00 and set-point temperature (22 degrees) starting at 09:00, the energy conservation rate, compared to the typical control was highest at 2.33%. In terms of thermal mass, the energy conservation rate was highest at 3.57% when compared to typical control when it was controlled to be set at 14.6 degrees at 07:00, 17.6 degrees at 08:00 and set-point temperature (22 degrees) starting at 09:00.

CONCLUSION

This study analyzed the thermal characteristics of concluded the set-back control accordingly. As for the thermal mass model, it maintained a relatively higher temperature when there was no air conditioning. In a typical control, the night time heating rate was relatively lower in the case with thermal mass. As for set temperature reset, the energy conservation rate varied depending on the heat storage capacity. The point at which temperature began to rise in the case with the highest energy conservation rate also varied. This indicates that the thermal characteristics of buildings with heat storage are distinct and that they must be taken into account to control when aiming for energy conservation.

Setback control is an HVAC control method to conserve energy in heating or air conditioning. Peak shaving through night setback control during winter months when heating is used not only affects energy conservation in a building but also the energy supply infrastructure. In order to apply appropriate setback control, affecting factors according to the characteristics of the building must be taken into account. As such, this study presents an optimal setback control method according to the heat storage function of office buildings.

A test of the function of the suggested setback control was conducted using EnergyPlus, an energy analysis program. For the analysis model, a small office among the DOE reference model was used. Depending on the control method, they were categorized into no setback model, typical setback model, and set temperature reset model. The thermal mass in each model changed depending on the location of the thermal insulating material of the structure. For the set temperature reset model, a separate set-back operation time was set.

The analysis results show that the thermal mass, in accordance with the location of the thermal insulation material, is a factor affecting the zone air temperature. The suggested model, when compared to the typical setback model, had a smaller peak load and monthly energy usage, and called for a different control method depending on the heat capacity.

ACKNOWLEDGEMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP) and the Ministry of Trade, Industry & Energy(MOTIE) of the Republic of Korea (No. 20174010201320).

This research was supported by the Yonsei University Research Fund of 2018220038.

REFERENCES

[1] Yuzhen Peng, Adam Rysanek, Zoltan Nagy, Arno Schulter, “Occupancy learning-based demand-driven cooling control for office spaces,” Building and Environment, vol. 122, pp. 145-160, September 2017.

[2] Trent Hilliard, Lukas Swan, Zheng Qin, “Experimental implementation of whole building MPC with zone based thermal comfort adjustments,” Building and Environment, vol. 125, pp. 326-338, November 2017.

[3] Jin Woo Moon, Sung Kwon Jung, “Algorithm for optimal application of the setback moment in the heating season using an artificial neural network model,” Energy and Buildings, vol. 127, pp. 859-869, September 2016.

[4] Duk Joon Park, Ki Hyung Yu, Yong Sang Yoon, Kee Han Kim, Sun Sook Kim, “Analysis of a Building Energy Efficiency Certification System in Korea,” Sustainability, vol. 7.

[5] Manning M.M, M.C Swinton, F. Szadkowski, J. Gusdorf, K.Ruest, “The effect of thermostat set-back and set-up on seasonal energy consumption, surface temperature and recovery times at the CCHT Twin house facility,” ASHRAE Transactions 113, pp. 1-12, 2007.

[6] Jin Woo Moon, Seung Hoon Han, “Thermostat strategies impact on energy consumption inresidential buildings,” Energy and Buildings, vol. 43, pp. 338-346, March 2011.

[7] John Ingersoll, Joe Huang, “Heating energy use management in residential buildings by temperature control,” Energy and Buildings, vol. 8, pp. 27-35, February 1985.

★★★