Analysis on the Level of Annual Heating/Cooling and Lighting Load of a Building according to Varying Projection Factors of External Horizontal Solar Shades

Gwang-Il, Park[1,*], Jong-Hwan, Ko[1], Sun-Hye, Mun[1], and Jung-Ho, Huh[1]

[1] Department of Architecture, University of Seoul
Seoul, Republic of Korea

ABSTRACT
Along with the growing concern in buildings of reduced energy consumption, the installation of effective solar shading device is being spotlighted. The solar shading device has an advantage of effective control over energy consumption in buildings without changing the envelope of each building. The movable solar shading devices developed to get over limitations of fixed solar shading devices intend to provide residents with thermal and visual pleasantness in a way of changing the length of sunshade or the angle of slit depending on the position of the sun.

This study was designed to explore an effective operation of movable solar shading device for which the design of solar shading device and the cooling and lighting loads in building varying according to the presence of occupants were examined. Above all, the length of the extension of solar shading was calculated according to the solar angle and average height of windows. Based on the calculated length of the extension of solar shading, the applicability of solar shadings and the cooling and lighting loads to be varying according to the presence schedule of occupants were examined. For the application of the presence of occupants to the examination, the presence schedule of occupants determined by the survey conducted through questionnaires inquired the presence of occupants in buildings at each time was used. For the application of the operation of movable solar shading device to be changing in accordance with the presence of occupants, the EMS module of EnergyPlus was used.

The ways of controlling movable solar shading device to be presented by results of the examinations to be conducted in this study are thus expected to become as the one of environmentally friendly architectural elements.

KEYWORDS
Horizontal shading, Projection factor, Heating and cooling loads, Lighting loads

INTRODUCTION
The application of most of elementary technologies for the green remodeling of buildings with the new and renewable energy equipment not only requires expensive initial investment but also needs difficult installation works thereof. On the contrary, the solar

*Corresponding author email: huhj0715@uos.ac.kr

shading device attached to buildings is a relatively cheaper alternative with comparatively easy installation. Thereby, the installation of solar shades is encouraged. In fact, the solar shades have been installed in many existing buildings in Europe (Choi, 2006). In Korea, the design standards for the 'Green Buildings' have been prepared since 2013 by the local government of Seoul Metropolitan City to promote the installation of solar shades. The Central Government of Korea also implemented the 'Act on the Support of Construction of Green Buildings' actively and made the installation of solar shades to buildings of total floor area over 3,000㎡ mandatory. In this study, the effects of the installation of external horizontal solar shades capable of blocking solar rays before they reach the inside of buildings and providing effective external views contrasting to typical blinds were examined.

Song (2016) examined the insolation to ordinary office buildings placed in Seoul Metropolitan Area that varied according to different projection of external horizontal solar shadings attached thereto, and found the projection factor of the value of 0.2 of the external horizontal solar shades blocked the insolation most effectively. In this study, the loads of the cooling, heating, and lighting purposes of buildings that were expected either to be decreasing or increasing by varying the projection factors of the external horizontal solar shades were examined along with the effects of the blocking of the insolation to buildings. Thereby, the values of effective projection factors of the external horizontal solar shades for the reduction of the amount of annul energy consumption in such buildings were derived.

METHODS

In this study, one laboratory room of a building in a university placed in Seoul was selected to set up conditions for the simulation conducted by using the simulation program EnergyPlus for the analysis of the loads of the cooling, heating, and lighting thereof according to varied projection factor of the external horizontal solar shades. For the analysis of the lighting load, the loads required to keep the illumination of 500lux (Illumination Standard for Laboratory Rooms, KSA) from the two 'Dimming Points' set

***Table 1**. Input Values for the Simulation*

Inputs	Descriptions	Inputs	Descriptions
Weather Data	Seoul Area	Population Density	0.14 people/㎡
Orientation of Building	Southward	Equipment	10.34 W/㎡
Height of Vertical Window	1.8m	Lighting	4.41 W/㎡
Size of Space (Room)	5.5 X 5.3 X 2.7	HVAC	Ideal Loads Air system
Set Indoor Temperatures	On heating: 18℃ On cooling: 26℃	Thermal Transmittance (External Wall)	0.21[W/㎡K]
Targeted Illumination	500 Lux		

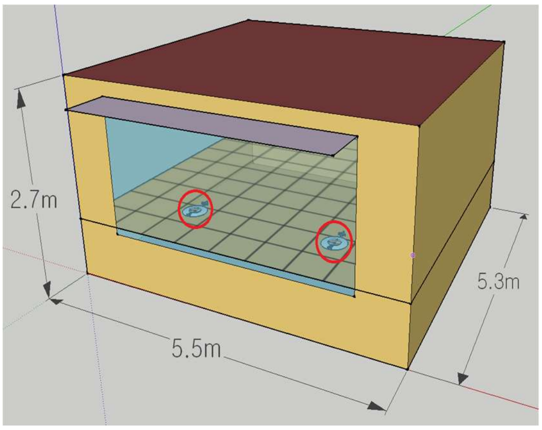

Figure 1. *Simulation Model of the Room*

at the height of 0.8m from the floor of the room were examined. The experimental model built up for the simulation comprised two walls; one southward with glass window and another one northward both contacting with outdoor air directly. The rest of the other walls were set as the walls free from the effects of varying outdoor air. The values inputted to the simulation program are as summarized in table 1; and the prepared simulation model of the room is as illustrated in Figure 1.

The external horizontal solar shade was applied to the above of the vertical window of 1.8m height in the wall southward. The projection factor (PF) of the external horizontal solar shade was defined as the ratio of the projection (P) of the solar shade to the height (H) of the window (P/H)[Song, 2016], and the PFs defined so according to each case are as represented in Table 2.

Table 2. *Projection Factors of the Horizontal Solar Shade*

Cases	Projection Factors	Projections
Case 1.	0.2	0.36m
Case 2.	0.4	0.72m
Case 3.	0.6	1.08m
Case 4.	0.8	1.44m
Case 5.	1.0	1.80m

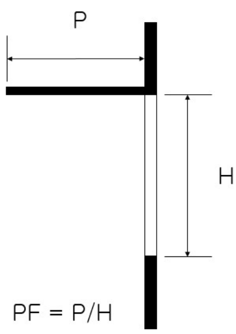

Figure 2. *Definition of the Projection Fator(PF) of the external Horizontal Solar Shade*

SIMULATION RESULTS

The simulation intended to identify the variation of cooling load of a building according to changing conditions of the application of external horizontal shade was carried out on 24th of July selected by the outdoor temperature of the day marked the highest level in the past weather data of Seoul metropolitan area.

Figure 3(a) shows the inflow of solar radiation on 24th of July to the building varied according to different projection factors of the external horizontal shade applied thereto. In the comparison of the inflow of solar radiation with the case of the building without

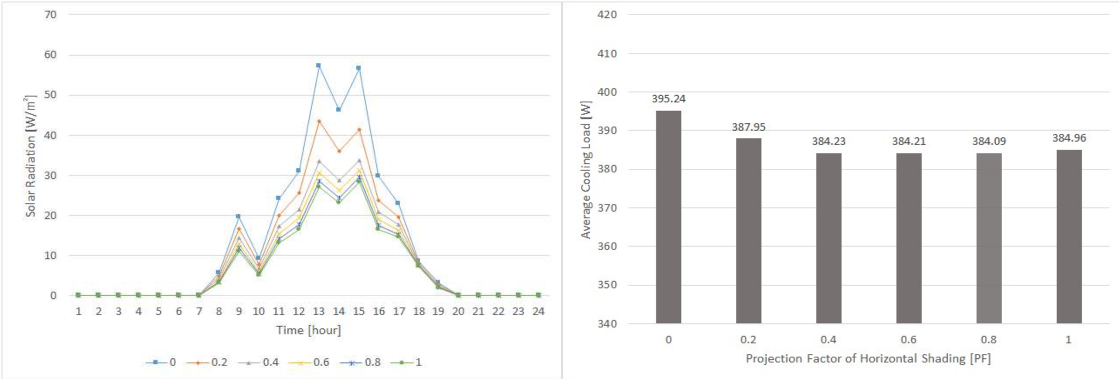

Figure 3(a). *The Inflow of Summertime Solar Radiation to the Building on 24th of July according to varied Projection Factors of the External Horizontal Shade*
Figure 3(b). *The Summertime Cooling Load of the Building on 24th of July according to varied Projection Factors of the External Horizontal Shade*

the external horizontal solar shade, the simulation rendered the values of the inflow of solar radiation to the building reduced by 20.36%, 33.42%, 39.19%, 43.47%, and 46.53% respectively at values of each projection factor of 0.2, 0.4 0.6, 0.8, and 1.0.

Figure 3(b) represents the cooling load of the building varied according to each case of different projection factors of the external horizontal solar shade applied to the building. The values of the cooling load resulted from the simulation also decreased by 1.84% 2.79% 2.80%, and 2.82% respectively at values of each projection factor of 0.2, 0.4, 0.6, and 0.8. However, at the value of the projection factor of 1.0, the cooling load of the building increased. The result was concluded that it would be attributable to the increase of the lighting load of the building unavoidably increased by the complete shutoff of the sunlight.

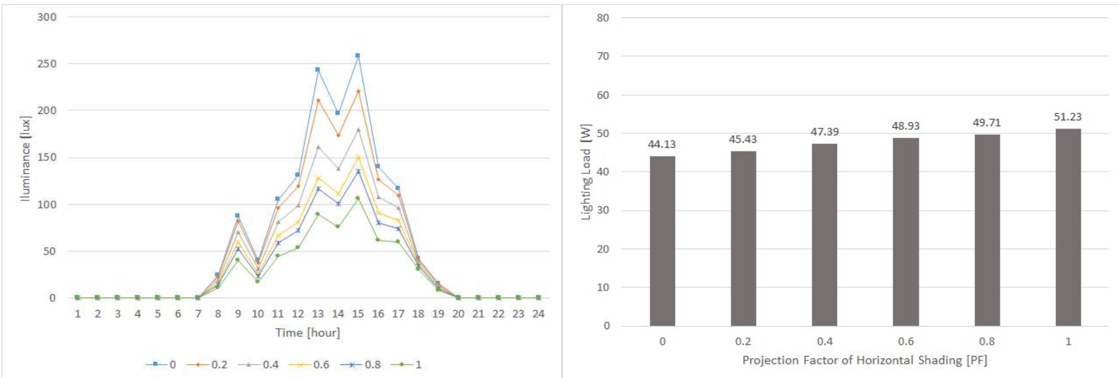

Figure 4(a). *The Summertime Illumination on Working Plane of the Building on 24th of July according to varied Projection Factors of the External Horizontal Shade*
Figure 4(b). *The Summertime Lighting Load of the Building on 24th of July according to varied Projection Factors of the External Horizontal Shade*

Figure 4(a) shows the summertime illumination on working plane of the building varied according to each case of different projection factors of the external horizontal solar shade applied to the building. The simulation rendered the values of the illumination on the working plane of the building decreased by 10.37%, 26.03%, 38.49%, 44.89%, and 57.29% correspondingly to the values of each projection factor of 0.2, 0.4, 0.6, 0.8, and 1.0.

Figure 4(b) also represents the varied summertime lighting load of the building resulted from different projection factors of the external horizontal solar shade applied to the building. The resulted values of the lighting load of the building increased by 2.94%, 7.38%, 10.88%, 12.64%, and 16.09% according to the values of each projection factor of 0.2, 0.4, 0.6, 0.8, and 1.0.

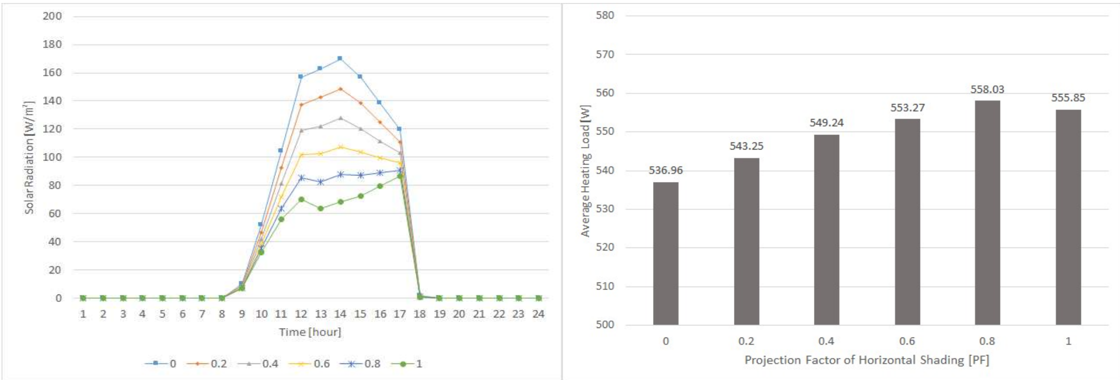

Figure 5(a). *The Inflow of Wintertime Solar Radiation to the Building on 24th of January according to varied Projection Factors of the External Horizontal Shade*
Figure 5(b). *The Wintertime Heating Load of the Building on 24th of January according to varied Projection Factors of the External Horizontal Shade*

The simulation intended to identify the variation of heating load of a building according to different conditions of the application of external horizontal shade was also carried out on 24th of January selected by the outdoor temperature of the day marked the lowest level in the past weather data of Seoul metropolitan area. Figure 5(a) represents the wintertime inflow of solar radiation on 24th of January to the building varied according to different projection factors of the external horizontal shade applied to the building.

The simulation produced the values of wintertime inflow of solar radiation to the building reduced by 11.21%, 21.93%, 31.92%, 41.24%, and 49.91% respectively at values of each projection factor of 0.2, 0.4, 0.6, 0.8, and 1.0. The level of wintertime inflow of solar radiation was higher than that of the summertime. This was attributable to the relatively lower altitude of the sun in wintertime.

Figure 5(b) shows the wintertime heating load on 24th of January of the building varied according to different projection factors of the external horizontal shade applied to the building. The simulation outputted the values of the wintertime heating load of the building increased by 1.17%, 2.29%, 3.04%, and 3.92% respectively at different values of the projection factor of 0.2, 0.4, 0.6, and 0.8. However, when the value of projection factor increased from 0.8 to 1.0, the simulation showed the decreasing of wintertime heating load of the building. This was estimated that it could be attributable to the increased heat radiation from lighting equipment in the building lit up due to the complete shutoff of the sunlight.

The annual heating/cooling and lighting load of the building resulted from the simulation conducted by varying the values of the projection factor of the external horizontal solar shade applied to the building showed the lowest level of annual heating/cooling and

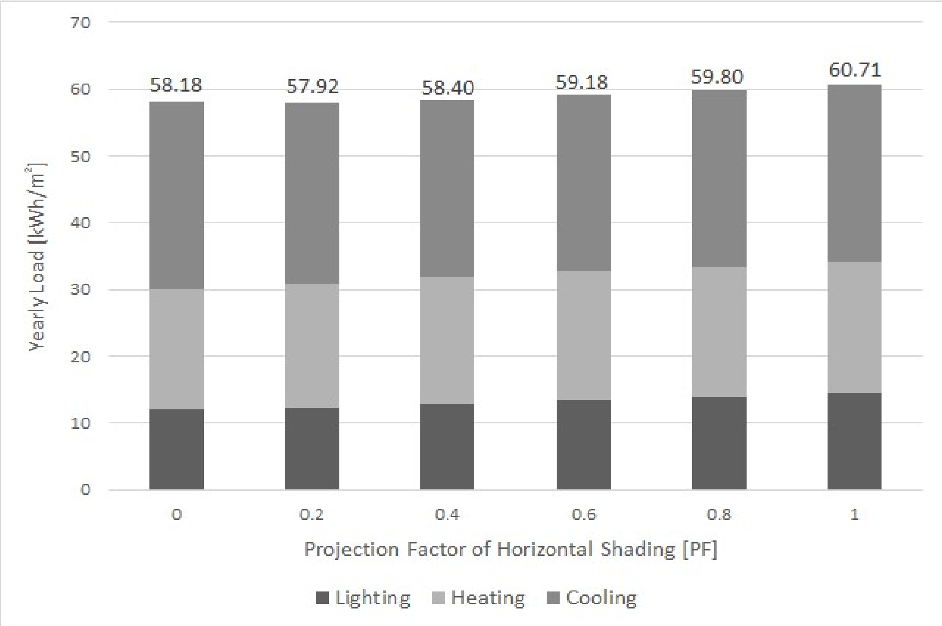

Figure 6. *Annual Heating/Cooling and Lighting Load of the Building corresponded to different Projection Factors of the External Horizontal Shade*

lighting load of the building at the value of 0.2 of the projection factor. At this level of the projection factor, the annual cooling load decreased thereby was bigger than the sum of the annual heating and lighting load of the building due to the weight assigned to the cooling load bigger than the weight assigned to the other annual heating and lighting loads of the building in the simulation. Besides, the amount of annual heating and lighting loads energy consumption of the building equipped with the external horizontal solar shade exceeds the level of that of the building free from the application of external horizontal solar shade.

CONCLUSIONS

This study was designed to derive the projection factor of the external horizontal solar shade attached to the building that allows the most efficient consumption of annual energy for the building. The simulation to find the annual level of the energy consumption for heating, cooling, and lighting of the building at different projection factors was carried out. The simulation outputted the projection factor of 0.2 of the external horizontal solar shade as the most efficient level minimizing the entire annual energy consumption for heating, cooling, and lighting load of the building.

As a result, the external horizontal solar shade was concluded that it would be effective for the reduction of the cooling load of a building in summertime. Contrarily, it appeared that it has a disadvantage of increasing the energy consumption for heating and lighting load especially for buildings the weight assigned to the heating or lighting load is higher than that assigned to the cooling load. To resolve the problems of the relatively excessive increasing of the consumption of heating and lighting energy of a building with the application of solar shades thereto, the operational solar shading mechanism seems necessary. The operational solar shading device should be applied to buildings by realizing the embodiment of the mechanism of solar shading control. This application thus could be beneficial for the buildings by enabling the provision of pleasant indoor environment for occupants and efficient energy consumption thereof.

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