KIEAE Journal, Vol. 17, No. 1, Feb. 2017, pp.23-28.

KIEAE Journal

Korea Institute of Ecological Architecture and Environment

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The verification about possibility of introducing Window to Floor Ratio as design index for building energy performance

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ABSTRACT

Purpose: Many design index that are using in planning phase have been developed. The most popular things among them are Window to Wall Ratio and Surface to Volume Ratio. However there are some limits. Window to Wall Ratio cannot consider building size and Surface to Volume Ratio cannot do Window to Wall Ratio. Accordingly, in this paper, the Window to Floor Ratio was proposed that it can be considered both building size and Window to Wall Ratio. And analyzed correlation of energy demand. **Method**: For the test, 16 modules with the size of 6m x 6m x 4m were used to make 35 models with the same volume. The simulation was conducted to 945 cases using the window-to-wall ratio of 30, 50 and 70 % in three areas such as Seoul, Gwangju and Jeju and three kinds of windows. And IES_VE was used. **Result**: The findings above show that the Window to Floor Ratio that can be considered both building size and Window area have to become as design index. It was found out that design criteria with SHGC is necessary, not with the thermal performance (U-value). It is needed to additional analysis about residential building and the effect of 24-hours heating and cooling condition. It plans to carry out research to establish design indicators for climatic conditions in the country and building applications.

KEYWORD

건물에너지
태양열취득계수
창바닥비
업무용건물
설계지표

Building energy
Solar heat coefficient
Window to floor ratio
Office building
Design index

ACCEPTANCE INFO

Received Jan. 9, 2017
Final revision received Jan. 25, 2017
Accepted jan. 30, 2017

1. Introduction

1.1. Background and Purpose of Study

The energy consumption of building is influenced by various element technologies. These technologies can be represented by passive or active technologies. However, while these technologies are often considered in the building design stage, they are generally selected based on the aimed energy performance and cost. However, the building shape, window area and direction which are basically considered in the building design stage are the most common planning factors .

Design indicators are the relationship between these design factors and building energy performance. Various design indicators are being developed and utilized all over the world. However, most of these indicators are focused on residential buildings where the heating energy becomes main, and it is analyzed that there is a limit to apply to office buildings like this paper. Therefore, this study was performed to comprehensively analyze the impact on building energy of area, window to wall ratio, window performance, and shape on building energy in buildings with the same volume, and to provide reasonable design indicators by deriving the correlation with various design indicators.

1.2. Method and Scope of Study

This study, as simulation study using IES_VE, was performed using weather data of Seoul, Gwangju and Jeju area. This is because energy saving design standards are set up in South Korea, which is divided into the central region of Seoul, the southern region of Gwangju, and the Jeju region. And window area was targeted to 30, 50, 70%. The window performance was also analyzed in three types considering heat transmission coefficient and SHGC.

The analytical model was defined by using column spacing and floor height of 6 m * 6 m * 4 m office building, unit module, and performed energy performance and sensitivity analysis for 35 models that can be composed through 16 modules combination of previous studies. As design indicators, the correlation was derived using the window to wall ratio, surface to volume ratio, window to floor ratio, etc.

2. Analysis Model and Input Conditions

This study is the comprehensive analysis of the effects of window performance changes on the basis of various building

pISSN 2288-968X, eISSN 2288-9698
http://dx.doi.org/10.12813/kieae.2017.17.1.023

shapes with the same volume according to the combination of unit module. For this, a model with 6 m × 6 m and 4.2 m height with ratio of lateral to longitudinal length 1: 1 is presented, and 16 cases of module combinations presented in the previous study (Choi Won-gi et al., 2007) were further subdivided, and simulation analysis was performed on this. Table 1 through Table 3 summarize the arrangement patterns of 1, 2, 4, 8, and 16-floor models according to module combination. The wall composition and property values for the unit module are set as shown in Table 4 based on the building energy saving design standards applied since January 2013 announced by the Ministry of Land, Infrastructure, and Transport. Table 5 summarizes the performance data of the applied windows. As can be seen in Table 6, the selection standard for the window performance consists of single Low-e double glazing, which is the most widely used, triple Low-e double glazing, which has low solar heat gain coefficient (SHGC), and a single Low-e triple glazing, which has similar insulation performance is to this but high solar heat gain coefficient (SHGC). The reason for choosing this window performance is to compare the maximum insulation performance and the general insulation performance that can be composed by double glazing, and next, to compare the effect when the insulation performance (heat conduction ratio) is similar, but SHGC is different.

Table 1. 1st Floor Analysis Cases According to Module Combination

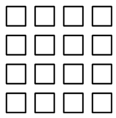
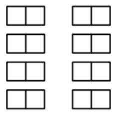
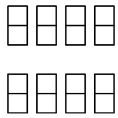
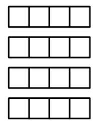
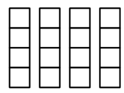
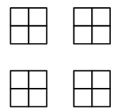
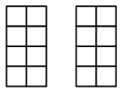
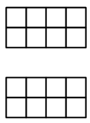
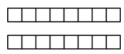
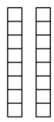
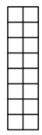
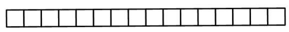
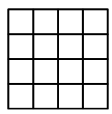
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model Position						
	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Model Position						
	Model 13	Model 14			Model 15	
Model Position						

Table 2. 2nd Floor Analysis Cases According to Module Combination

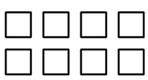
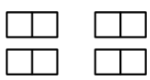
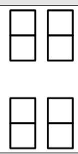
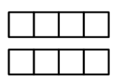
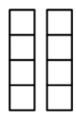
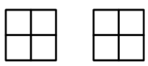
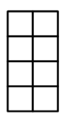
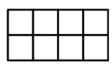
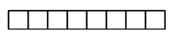
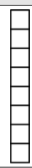
	Model 16	Model 17	Model 18	Model 19	Model 20
Model Position					
	Model 21	Model 22	Model 23	Model 24	Model 25
Model Position					

Table 3. Over 4th Floor Analysis Cases According to Module Combination

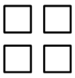
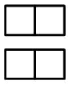
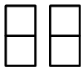
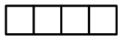
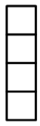
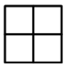
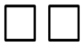
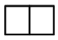
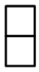
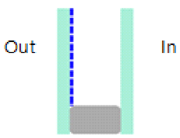
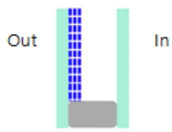
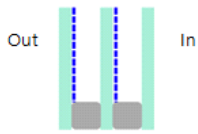
	Model 26	Model 27	Model 28	Model 29	Model 30
Model Position					
Number of stories	4	4	4	4	4
	Model 31	Model 32	Model 33	Model 34	Model 35
Model Position					
Number of stories	4	8	8	8	16

Table 4. Material Properties & Wall Composition

Material	Conductivity (W/m.℃)	Density (kg/m³)	Specific Heat (J/kg.℃)
1) Stone(Granite)	3.30	2,700	900
2) Insulator(Extrusion Special Grade)	0.027	600	1,400
3) Concrete(1:2:4)	1.60	2,200	1,000
4) Cement Mortar(1:3)	1.4	2,000	
5) Gypsum Board	0.18	800	837

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	U-value (W/m².℃)
Exterior Wall	1) 30㎜	2) 90㎜	3) 150㎜	4) 20㎜	5) 25㎜	0.267
Roof	3) 100㎜	2) 140㎜	4) 30㎜	2) 150㎜		0.182
Floor	3) 70㎜	4) 30㎜	3) 100㎜	2) 85㎜		0.285
Slab	3) 150㎜	5) 25㎜				2.209
Inside Wall	5) 25㎜	3) 100㎜	5) 25㎜			1.785

Table 5. Glazing Configuration & Properties

	Single Low-e Double Glazing			**Triple Low-e Double Glazing**			**Single Low-e Triple Glazing**		
Spec.	 IGDB 5248			 IGDB 5186			 IGDB 5248 2 Panes		
	24mm(6+12+6)			28mm(6+16+6)			42mm(6+12+6+12+6)		
	U-Value	SHGC	VLT	U-Value	SHGC	VLT	U-Value	SHGC	VLT
	1.7519	0.6155	0.734	1.0997	0.1678	0.277	1.0178	0.4929	0.615
U-value of Window	1.9039 W/m²K			1.3170 W/m²K			1.2433 W/m²K		

In order to analyze the heating and cooling energy demand of the building, it is necessary to present various setting values such as occupancy density, illumination heat generation, device heat generation, occupancy schedule, and heating and cooling schedule, and the factors and setting conditions of the building subject to simulation in this study are assumed as shown in Table 6.

Finally, the meteorological data used were analyzed by applying Seoul, Gwangju and Jeju area weather data provided by IES_VE.

Figure 1 shows the distribution of monthly average outside temperature, and Figure 2 shows the Global Horizontal Irradiance distribution.

Examining Global Horizontal Irradiance, it can be seen that Seoul, Gwangju and Jeju are quite different. In particular, in case of Jeju, the distribution of Global Horizontal Irradiance is very high from March to September. In case of Seoul and Gwangju, it can be seen that the values of Global Horizontal Irradiance are relatively high in April, May and June.

These regional differences, that is, the energy performance of the same-volume buildings according to the central, southern, and Jeju regions, are also compared and analyzed to provide reasonable standards for each region, and further suggested the reasonable window standards and window to wall ratio standards.

Table 6. Simulation Input Data

Contens	Input Data
Room Temperature	Heating : 20℃ Cooling : 26℃
Building Operation Schedule	Weekdays : 08:00~18:00 Weekend : Off
Person	0.11 people/㎡
Human	126 W/person
Facilities	15 W/㎡
Target Illumination	400 lux
Lighting	3.4 W/㎡·100 lux (Non-Dimming Control)
Infiltration & Ventilation	0.3 times/h, 60㎥/man.h [Large Office]
HVAC	Ideal Load Air System
Wether Data	Seoul, Gwangju, Jeju IES_VE Data

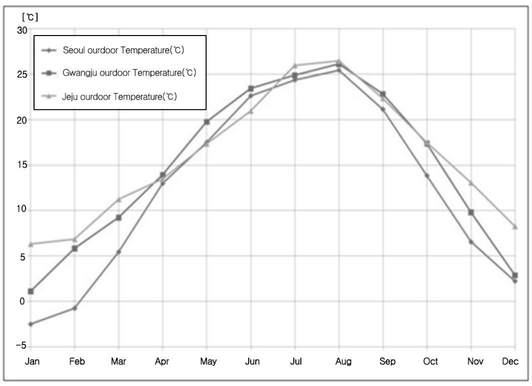


Fig 1. Regional Monthly Average Outdoor Temperature

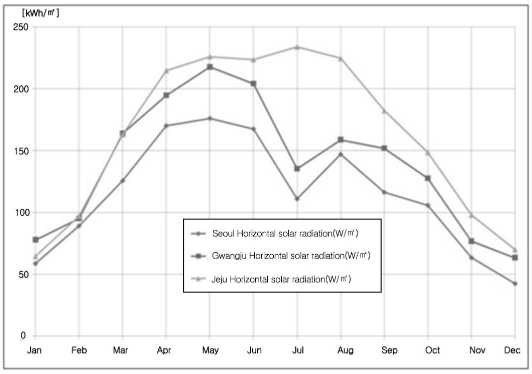


Fig 2. Regional Monthly Average Total Solar Radiation

3. Analysis of Simulation Results

3.1. Analysis of Energy Demand

Figure 3 shows the annual heating and cooling energy demand of single Low-e Double Glazing by model. Although there is a difference in each model, the distribution pattern of energy demand is very similar. In particular, it can be seen that the 70% model of the window to wall ratio in Jeju shows a difference of more than 30 MWh compared to the 30% model of the window to wall ratio.

Figure 4 shows the annual heating and cooling energy demand of the triple Low-e Double Glazing by model. Although there is a difference in the value of each model, it can be seen that the energy demand distribution is very low compared with the window made of single Low-e. And Jeju area is characterized by superior performance at the same window to wall ratio compared to other areas. Figure 5 shows the annual heating and cooling energy demand of single Low-e Triple Glazing by model.

Although there is a difference in the energy demand reviewed by model, it is very similar to that of the single Low-e double glazing, and in the model with excellent energy performance, the difference according to the window to wall ratio is not large, but in the model with relatively low the energy performance, the difference is about 40 MWh or more.

Figure 6 shows the distribution and correlation of regional energy demand according to the floor area ratio regardless of the window to wall ratio (WFR) in case of single Low-e double glazing. On the whole, the larger the window to wall ratio (WFR) is, the greater the energy demand is, which is the result of the analysis consistent with previous studies. However, there are some differences in the correlation equation, which is analyzed as a result of the difference in window performance.

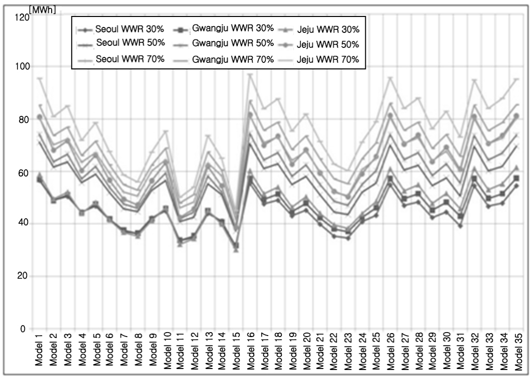


Fig 3. Anual Energy Demand of Single Low-e Double Glazing

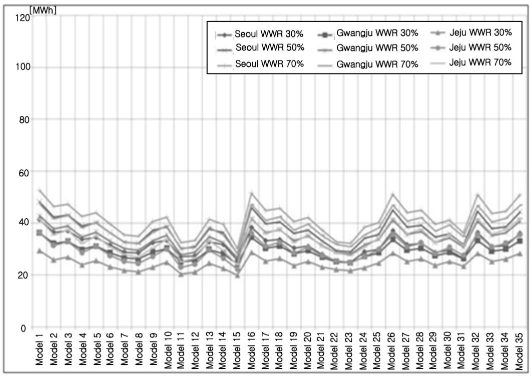


Fig 4. Anual Energy Demand of Triple Low-e Double Glazing

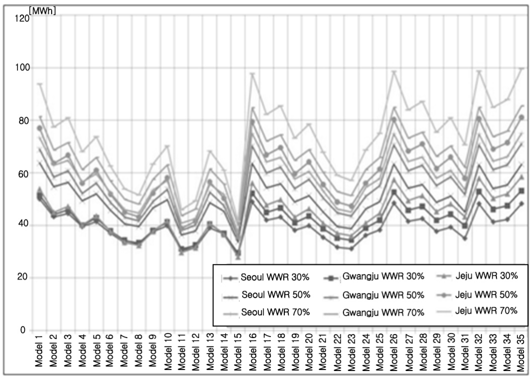


Fig 5. Anual Energy Demand of Single Low-e Triple Glazing

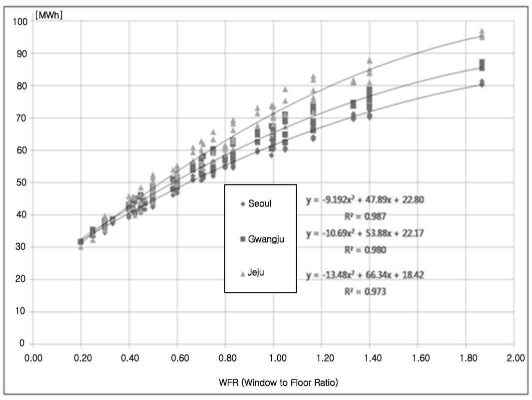


Fig 6. Regional Energy Demand of Single Low-e Double Glazing according to WFR

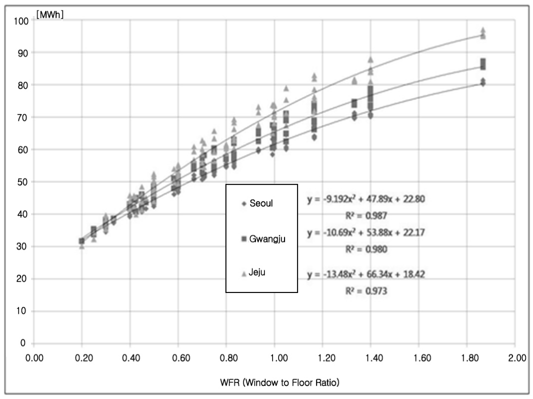


Fig 7. Regional Energy Demand of Triple Low-e Double Glazing according to WFR

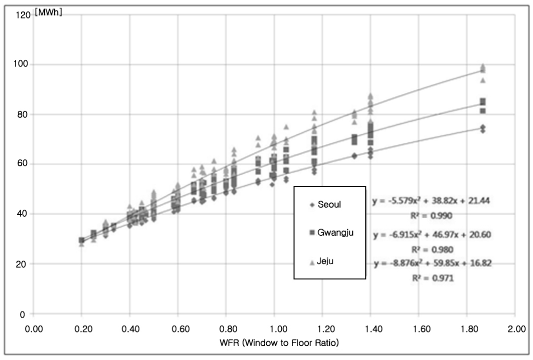


Fig 8. Regional Energy Demand of Single Low-e Triple Glazing according to WFR

Figure 7 shows the regional energy demand distribution and correlation according to the floor area ratio regardless of the window to wall ratio (WFR) in case of the Triple Low-e Double Glazing. On the whole, the larger the window to wall ratio (WFR) is, the greater the energy demand is, but as the analysis shows, Jeju region has the best performance as heat transmission coefficient is good and the window with low SHGC is applied.

Figure 8 shows the regional energy demand distribution and correlation according to the floor area ratio regardless of the window to wall ratio (WFR) in case of the Single Low-e Triple Glazing. On the whole, the larger the window to wall ratio (WFR) is, the greater the energy demand is, and shows similar pattern to the single Low-e Double Glazing.

However, it shows a pattern contrary to the triple low-e double glazing, and it can be confirmed that the energy saving effect can not be expected when the heat transmission coefficient is simply increased. Figure 9 shows the energy demand distribution according to the S/V ratio. It is considered that there is a limit to find any correlation and the analysis is omitted.

And figure 10 shows the energy demand distribution according to the S/V ratio. It is considered that there is a limit to find any correlation and the analysis is omitted.

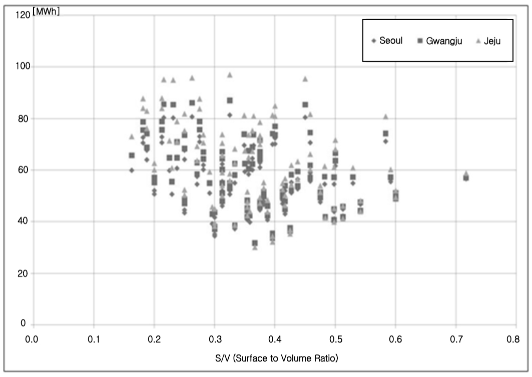


Fig 9. Regional Energy Demand of Single Low-e Double Glazing according to S/V rate

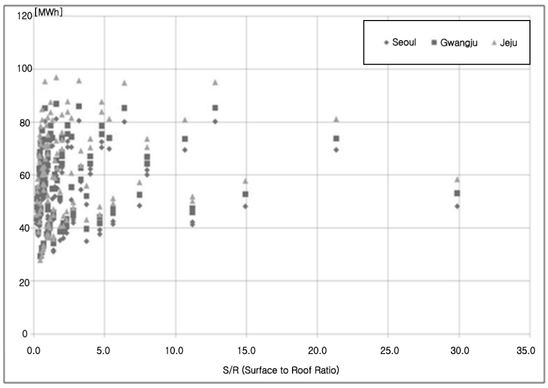


Fig 10. Regional Energy Demand of Single Low-e Double Glazing according to S/R rate

4. Conclusion

This paper conducted the analysis through simulation with a focus on the development of indicators available at the design stage concerning the global trends in the reduction of greenhouse gas emissions according to global warming. The results are summarized as follows.

First, the window to wall ratio, area volume ratio and area bottom ratio widely used as indicators are proved to be limitations in the design indicators

Second, as the window to wall ratio increases, the energy demand also increases, but there is a limit to derive the correlation as the region and window performance varies.

Third, by region, across all models, the correlation between mutual window to floor ratio (WFR) was proved to be proportional, and the window volume ratio (WVR) also proved to have the same correlation.

Fourth, it is reasonable to adopt Window to Floor Ratio as the design indicator for office buildings, which is because the building size and window area are considered simultaneously, and the window volume ratio can be adopted by the same principle.

Fifth, in order to reduce building energy consumption through the existing buildings energy-saving design standard, the standard for SHGC should be included and the standard based on Window to Floor Ratio (WFR) should be prepared.

Through the above study, it can be proved that the window to floor ratio (WFR) which can simultaneously consider the window area and the building size as the design indicator was the most desirable, and it is urgent to establish design standards through the solar heat gain coefficient (SHGC), not insulation performance.

Acknowledgements

This research was supported by a grant(16AUDP-B0791 04-03) from Architecture & Urban Development Research Program(AUDP) funded by Ministry of Land, Infrastructure and Transport of Korean government.

Reference

[1] Choi, W. K, Kim, H , J, Suh, S, J, A Study on the Analysis of Energy Consumption Patterns According to the Building Shapes with the Same Volume, Journal of the Korean Solar Energy Society, Vol. 27, No. 2, pp. 103-109, 2007.

[2] Yoon, Y, S, Choi, W, K, Shim, M, H, A Study on the Characteristics of the Energy Performance in Curtain Wall Building, Journal of Architectural Institute of Korea, Vol. 29, No.7, pp. 255-263, 2013.

[3] Yoon, J, H, A Study on the Predictive Model of the Energy Demand Rate According to the Window to Floor Ratio in Office Buildings, graduate school of Kyungbook University, Doctoral dissertation, 2015.06