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71

A Comparative Analysis of the Energy Load due to Window Area Ratio of Domestic Public Buildings

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ABSTRACT

In the case of public buildings, fast communication and transparency in the administration and the public, as well as ensuring visibility and lighting performance using a glass curtain wall is symbolically expressed through the transparent glass skin.

This study is a simulation in order to derive the basic data for the establishment of the improvement of the heating and cooling load analysis according to the window area ratio changes with respect to the high effectiveness of the government's large public building energy consumption analysis and green building certification system of guidelines was analyzed by a change in the energy load.

Glass curtain wall is light and visibility, the symbolic meaning of communication, etc., but is widely used in a variety of characteristics, in terms of energy consumption being disadvantaged sheath plan should have been. Design, including the Atrium, is much less energy than energy consumption by the window area ratio. Thus, while compliance with design guide lines, the atrium and I like the burden of a large space ratio and energy load consists of only glass suggest that require more research on that given in the guidelines.

KEYWORD

Building Type
Window ratio
Public building
Atrium
Energy Load

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1. Introduction

1.1. Background and objectives of the research

As we face the energy crisis and global warming, various systems and guiding principals at whole governmental level restrict the use fossil fuels to hinder green gas emission. Especially unlike industrial and manufacturing field including transportation and production, architectural fields where visible effect is shown much taking a relative advantage display these endeavors very much with reduction policy and energy usage control. Our nation has put its endeavor stability in its systematic approach for sustainable development and energy reduction of buildings in various fields starting from eco-friendly building validation program recently enacting green building security act to enable integrated management. Although domestic public buildings are supposed to have green building certification mandatorily, energy usage of newly constructed building after 2005 is two times of energy of average compared to old building constructed before according to the energy usage of public building of local government in 2008 announced in 2009. Especially these public buildings acquired the class better than excellence in green building related system but real energy usage of public building has been emphasized as social matter because of failure to get certified in energy efficiency in reality.

In the case of public buildings being constructed now, transparency in administration and quick communication with people as well as securing daylight performance and visibility are expressed symbolically through transparent glass envelope using glass curtain wall. But many examples called 'steamer public building', 'glass castle' are reported as a result of abusing the glass use thoughtlessly without considering energy consumption and the precise direction according to the design plan and local features. According to this, government proposed design guideline towards windows and doors but it is judged not effective because general windows and doors not considering big sized glass curtain wall and big space like atrium are the standard there.

Thus this research selected large public buildings composed of facade made of glass curtain wall expected to have much energy consumption on the basis of data announced in 2009 and analyzed the features of temperature distribution. Then variance in air-conditioning load of building through window ratio change was analyzed. With this, we would like to present the data for basic

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research in order to establish improvement plan of green building validation program and effectiveness analysis of design guideline.

1.2. Research method and its scope

As a basic research for establishment of improvement plan of green building validation system and effectiveness validation of design guidelines of reasonable glass curtain wall envelope plan towards energy consumption reduction, 3 new, large public buildings that showed very high energy consumption with the failure regarding class confirmation in building energy efficiency class validation system were selected despite the fact that they acquired excellence class and perfect class in eco-friendly building validation system. First, thermal distribution on the facade was surveyed using thermo-graphic camera then thermal loss and gained part were judged through thermal distribution status according to the monthly use of glass curtain. After that indoor energy load change was expected and the effect on energy consumption was analyzed. Using window ratio of facade, envelope plan features were comprehended and variance in air-conditional load of the building was calculated through simulation by changing window ratio according to the design guideline of doors and windows. Through calculated energy load, effectiveness of guideline was validated and correlation of energy load of space and atrium according to the window ratio was set basis in analyzing the effect of atrium plan in building plan on energy load of the building. Through this, we would like to draw improvement plan of green building validation system and guideline of windows and doors. Features of windows are the same to concentrate in load variance according to the window ratio change, and the external conditions such as awning were excluded. Besides, TRNSYS Ver.17 was used as a method to analyze the load of the building.

2. Theoretical study

2.1. Envelope plan and energy of the building

Enegy loss of the building occurs in windows and doors just like figure 1[1] and this is because they have low insulation efficiency which is the feature of the material compared to the wall or roof. Glass becomes the route of too much heat in the summer and the route of main heat loss in the winter thus design of windows and doors determine the amount of energy needed for air-conditioning in the building. One research result announced that thermal loss of glass from indoor to outside is 5-6 times that of wall with insulators. And in the case of United States, it was announced that the ratio of glass among energy consumption of the building takes up 5% of total national energy consumption. [2] Therefore windows and doors plan in envelope plan of the building must consider consumption amount, even energy loss according to the heat loss and gain not to mention the visibility and sunlight as factors with great influence on energy loss and consumption amount of the building.

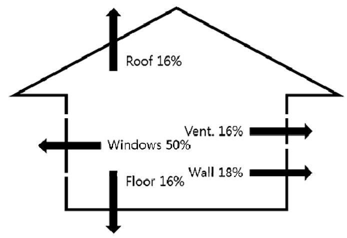


Fig. 1. Energy loss per part of the building

2.2. Energy feature and windows ratio of windows and doors

In order to determine the facade considering the weakness of heat loss and the advantages of visibility and ventilation, sunlight efficiency of windows and doors together, 『Design standard of energy saving of the building』 defined window ratio as 'window ratio regarding total envelop areaof the building excluding roof and floor' with the following equation.

$$windowratio = \frac{windowarea}{facadearea + windowarea} \times 100$$

Ministry of Land, Transport and Maritime Affairs(2012) proposed 「design guideline for windows and doors for energy saving of the building. It provides information of design factors of windows and doors on energy efficiency of the building and guideline according to the reduction effect calculating energy consumption amount depending on the conditions of various windows and doors design such as 4 directions, window ratio, kinds of windows and doors glass, presence of awning by direction, whether light is controlled after classifying the regions into central part/southern part/jeju region.

For window ratio, the scope of energy consumption amount according to the window ratio was analyzed dividing them into 20%, 40%, 60%, 80%. East and west direction showed almost proportional energy consumption amount in windows ratio and south direction showed rapid energy consumption amount in more than 40%, with north direction showing no significant increase in

1) Keith elder Envelop Building, 2000.

2) Collection of dissertation in summer conference of Korean system engineering, energy resources unit evaluation and air conditioning load interpretation according to the window ratio of offices by Jo JinHwan, Jung GwangSub, Kim YoungIll, Lee EunSeok 2012, p.442 ~445.

energy consumption according to the increase in window ratio. As a result, guideline recommend 40% in south and minimizes window ratio within 40% in east and west recommending 40% for south. Window ratio is not limited when windows and doors with very low thermal transmission coefficient for north.

The research to save energy of building is under progress in various aspects and the research on windows and glass efficiency, insulation efficiency related to envelope plan where energy loss occurs the most is being conducted as well. About windows ratio related to energy, Park SngKil a nd others (2005)[3] classified windows ratio into 10 stages from 10% to 100% using ECOTECT and showed the least energy load exists when windows ratio is 50-60% as a result of calculating yearly energy load. Jo JinHwang and others(2012) showed that energy consumption and air conditioning load reduces as area ratio decreases according to the windows ratio(30%, 40%, 50%) recommended in building energy saving design standard using TRNSYS. Likewise, researches on current windows ratio were done through simulation model such as TRNSYS, ECOTECT and the models used here are the ones modelled, not actual building being unable to reflect architectural design features.

Thus this research intends to analyze the correlation of energy load and windows ratio on the basis of building being used in reality.

3. Simulation conditions and building analysis

3.1. Building introduction

On the basis of investigation result of energy consumption of public government belonging to local government of Ministry of Public Administration and Security (now Ministry of Public Administration and Home Affairs) and Ministry of Knowledge Economy (now Ministry of Ministry of Tradem Industry and Energy) in 2009, public buildings with the condition of following <Table 1> were set as target buildings.

Table 1. Analysis of Target Buildings

	GBCC	Building Energy Efficiency Rating	Energy consumption per unit
A building	★★★ (2009.11)	Other than Class	603.3 (kWh/m²)
B building	★★★★(2010.7) Platinum(Seoul Green Building))	Other than Class	427 (kWh/m²)
C building	★★★ (2011.11)	Other than Class	791.3 (kWh/m²)

Selected public buildings are the ones that failed to get certified in energy saving class validation system of the building although they acquired the class better than excellence in eco-friendly building

Table 2. Architectural Overview of the target building

	A building	B building	C building
Location	Yeosu-dong, Jungwon-gu, Seongnam-si	Itaewon 1-dong, Yongsan-gu, Seoul	Samga-dong, Cheoin-gu, Yongin-si
Building Area	11,074.34m²	7,670.66m²	4,934.87m²
Gross Area	72,746.64m²	59,177.20m²	44,668.79m²
Atrium	9046.96m² (12.4%)	2781.34m² (4.7%)	1295.4m² (2.9%)
Building Coverage	14.87%	56.83%	28.69%
Floor Area Ratio	64.39%	180.43%	259.70%
Size	9F, B2F	10F, B5F	16F, B2F
Key Facility	Administrative facilities Civil work facilities Civic and cultural facilities City council	Ward Public Health Culture and Arts Center City Assembly	Public service facilities
Structure	steel, steel framed reinforced concrete construction	R.C, steel framed reinforced concrete construction	steel framed reinforced concrete construction
Exterior Finish	THK24 color Low-E double glazing, THK24 color double glazing, glass, Aluminum composite panel, Aluminum sheet	THK24 low reflection Low-E double glazing, THK24 pattern double glazing, granite	THK24 low reflection color double glazing, THK30 Granite burner grill
Shape			

3) Conference dissertation of Architectural Institute of Korea, Research on proper windows ratio of industrial buildings seen with energy efficiency, Park SngKil and Yu HoCheon2005, p.487～490.

validation program. This shows that excellent efficiency is not guaranteed even in the aspect of energy usage such as green house gas emission and reducing the used amount of energy just like the objectives of system even in the case of excellence class of eco-friendly building validation system thereby expressing the problems in effectiveness of the system directly. As used amount of energy and things to be improved in the system gain their weight, green building validation standard was established including similar eco-friendly system and 2013 building energy efficiency class validation program for improvement and integration however it is judged they still have their intrinsic problems since they categorize each system in one big frame without proposing clear direction or actual energy reduction then applying the methods before.

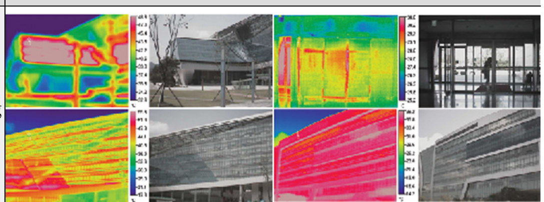
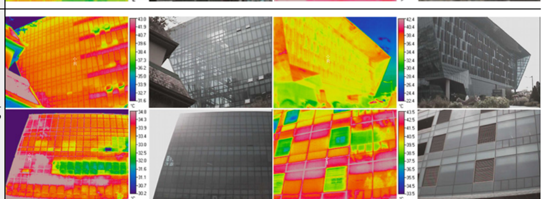
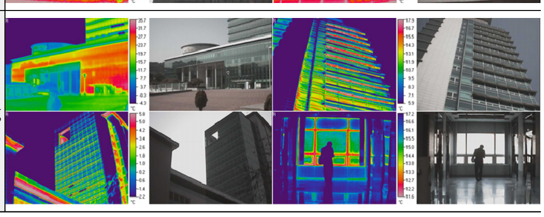
Following <Table 2> summarizes building outline of target building.

3.2. Thermal distribution features of envelop according to the measurement of thermo-graphic camera

All of target buildings of analysis had their exterior finish with curtain wall so acquisition and heat loss through envelope at high level is expected and heat distribution of envelope was measured through thermo=graphic camera from August 7th, 2012 to August 8th, 2012.

Temperature difference in envelop more than 10℃ was shown on average with maximum temperature of 18℃ between glass curtain wall and other envelope material. Although it can be shown differently according to the features of material and direction, in the case of B public building with high windows ratio curtain wall on south facade was 43.5℃ while ambient temperature is 33.2℃, and even on envelope such as the lowest frame it was shown higher than 33℃ supporting the judgement that heat transmission towards indoor would be higher if envelope with high heat conductivity is used. These phenomena increase indoor temperature and cooling load also increases in order to maintain pleasantness. Similarly, winter season was also expected to bring increase in air-conditioning load together with temperature reduction by cold ambient temperature affecting indoor continuously depending on the high thermal conductivity of material. It was judged that energy consumption would increase geometrically as energy load increases.

Table 3. Analysis of Target Buildings

	Photo
A building	
B building	
C building	

3.3. Windows ratio of the target building

Followings distinguish the ratio of envelope to windows and doors of the target building. Since it has high windows ratio overally, it was expected that calculation of air-conditioning load would be difficult because of high influence of ambient temperature.

Table 4. A Building Window area ratio

	South	North	East	West
Main exterior	THK24 color Low-E double glazing,			
Coefficient of over-all heat transmission	2.84	2.24		
Glass shading coefficient	0.56			
Window area ratio(%)	73.82	63.46	32.96	23.88

Table 5. B Building Window area ratio

	South	North	East	West
Main exterior	THK24 low reflection Low-E double glazing			
Coefficient of over-all heat transmission	2.84	2.24		
Glass shading coefficient	0.56			
Window area ratio(%)	72	48	70	74

Table 6. C Building Window area ratio

	South	North	East	West
Main exterior	THK24 low reflection color double glazing			
Coefficient of over-all heat transmission	2.4			
Glass shading coefficient	0.56			
Window area ratio(%)	61.98	21.54	41.39	32.51

3.4. TRANSYS

TRNSYS is a program used in dynamic thermal load calculation and has an excellent compatibility for it has module structure. It has various Plug-In such as Simulation Studio used in load calculation that links general causes, TRNBuild that inputs detailed data and constructs building information, TRNSYS 3D that enables more convenient and detailed input of building information by syncing with sketchup. This research composed the case model of sketchup and TRNSYS 3D, set energy load value and internal property value through TRNBuild, calculated final products through Simulation Studio.

3.5. Simulation conditions and methods

Climatic conditions put for building energy interpretation were weather data provided from TRNSYS 17 (KR-Seoul-471080.tm2) and simulation conditions are following <Table7>, <Table8>.

Table 7. Set-Point of Room Conditions

	Dry-bulb Temperature	Humidity
Summer	26℃	50%
Winter	18℃	40%

Table 8. Window area ratio

	Ratio		
Case1	Original window area ratio		
	A: 60.7%	B: 65.8%	C: 61.3%
Case2	50%		
Case3	40%		

Indoor temperature condition was fixed to energy plan and electricity provision that government pronounced thus set as 26℃ in summer and 18℃ in winter, with humidity calculated by climate conditions. In the case of indoor schedule, it is 'work day' which is a basic item and in order to focus on windows ratio of curtain wall simulation conditions of general office building were put not reflecting remarks.

In the case of windows ratio, it was considered that changes in reduction regarding windows ratio of energy load could be judged analyzing 50% of middle value and current windows ratio which represents more than 60% since the recommended value of the government proposes east and west direction 40%. When it is smaller ratio, this researche excluded that case for it was already analyzed in guideline.

4. Simulation result analysis and atrium

4.1. A public building

As simulation results, Case 2 where reduced windows rate to 50% that of Case 1 had decreased heating load and cooling load by each 34MWh, 108MWh, Case 3 where reduced windows ratio to 40% showed 221MWh, 178MWh reduction. Heating load each decreased by 5.8%, 9.6% showing reduction ratio within 10% but cooling load decreased by 24.4%, 40.2% showing nearly half reduction ratio when windows ratio was decreased to 40% supporting the judgement that 40% would be more advantageous in energy consumption saving than 50% windows ratio.

Table 9. Load change according to the window area ratio(A)

Dvision	Case1 (Original)	Case2 (50%)	Case3 (40%)	Ratio(%)	
				C1-C2	C1-C3
Heating(MWh)	2,289	2,155	2,068	5.8	9.6
Cooling(MWh)	443	335	265	24.4	40.2

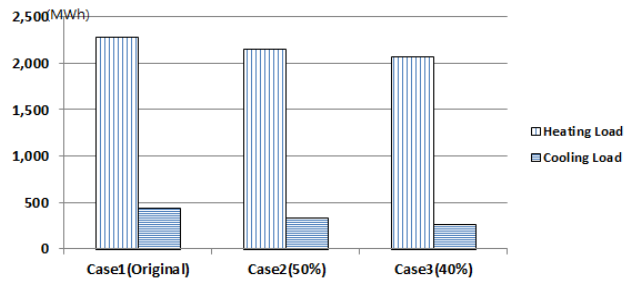


Fig. 2. Load graph(A)

4.2. B Public Building

As simulation results, Case 2 that decreased windows ratio to 50% compared to Case 1 which is the comparison target had yearly heating load and cooling load decreased by each 145MWh, 27MWh and Case 2 where windows ratio was decreased to 40% had them decreased by each 159MWh, 36MWh. Heating load showed a little higher than 10% reduction ratio having decrease rate of each 11%, 12.1% while cooling load having them at 31.5%, 42.5% showing nearly half reduction ratio although absolute reduction amount was shown high when windows ratio was decreased to 40% supporting the judgement that 40% would be more advantageous for energy saving reduction than 50% windows ratio like A public building .

Table 10. Load change according to the window area ratio(B)

Dvision	Case1 (Original)	Case2 (50%)	Case3 (40%)	Ratio(%)	
				C1-C2	C1-C3
Heating(MWh)	1,321	1,176	1,162	11.0	12.1
Cooling(MWh)	85	58	49	31.5	42.5

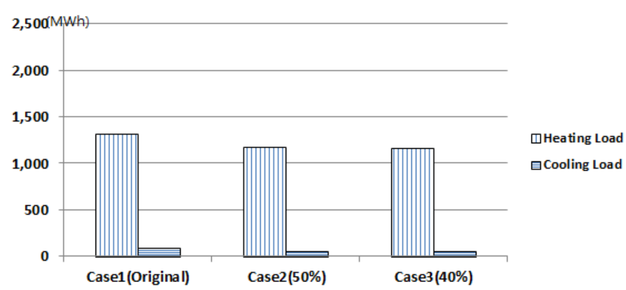


Fig. 3. Load graph(B)

4.3. C Public Building

As simulation results, Case 2 where windows ratio is decreased to 50% compared to Case 1 which is the comparison target had decreased yearly heating load and cooling load each by 1,087MWh, 27MWh and Case 3 where windows ratio is decreased to 40% had them decreased each by 1,101MWh, 36MWh. Heating load had them decreased them each by 49.1%, 49.7% while cooling load by 32.9%, 43.8% showing the reduction amount nearly half both air-conditioning load when windows ratio is decreased to 40%. Especially heating load shows very much reduction amount compared to A and B public building and it is judged that C public building as well would have more advantages in energy saving reduction in 40% than in 50% of windows ratio.

Table 11. Load change according to the window area ratio(C)

Dvision	Case1 (Original)	Case2 (50%)	Case3 (40%)	Ratio(%)	
				C1-C2	C1-C3
Heating(MWh)	2,215	1,128	1,114	49.1	49.7
Cooling(MWh)	82	55	46	32.9	43.8

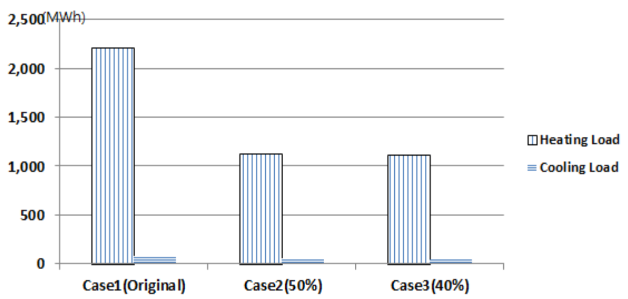


Fig. 4. Load graph(C)

4.4. Air-conditioning load by atrium

In the case of most public building constructed after 2005, glass curtain wall was used as envelope finish in large buildings in most cases additionally designed with atrium which is a large glass space. According to Kim NanJung (2014), among 19 public buildings of local government built between 2005~2009, 16 applied atrium. 3 large buildings also are public ones that planned atrium and high, large space made of glass curtain wall with high heat loss was expected to have much energy consumption in order to maintain pleasant conditions of atrium.

Following <Table 12> shows the calculation of energy load amount after dividing atrium and general buildings through zoning by zones on the basis of current building plan. Although the load ratio that atrium takes is shown differently according to the areaand features of atrium it was judged that atrium has disadvantages in energy loss aspect since the ratio of atrium in energy load is shown at least two times higher when comparing the total floor area to the arearatio of atrium.

For heating load, A public building and B public building has each 12.4%, 4.7% areacompared to total floor area with perpendicular atrium directing south but were analyzed to spend much more energy in atrium since they show heating load ratio of 20.7%, 9.3%. For C public building, area was low with 2.9% but since 3 faces of it were adjacent to envelope, it was analyzed to be very disadvantageous in the aspect of energy loss and consumption with the ratio of atrium's heating load taking up 11.3% of total heating load.

Table 12. Atrium ratio of Heating load

	Except Atrium (MWh)	Atrium((MWh)	Ratio(%)	Atrium(%)
A building	1,815	474	20.7	12.4
B building	1,198	123	9.3	4.7
C building	1,965	250	11.3	2.9

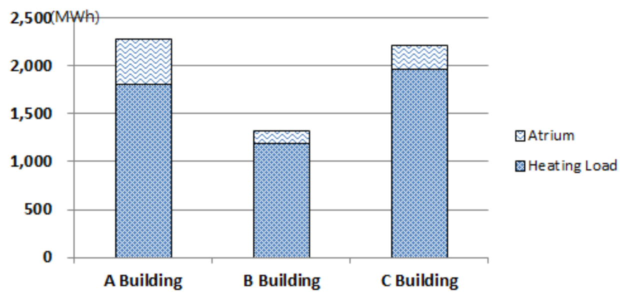


Fig. 5. The ratio of Heating load and Atrium

In the case of cooling load as well there are cases where ratio of load amount in atrium is lower or similar but it was analyzed to be disadvantageous in energy consumption aspect more than general architectural parts. Much more influence can be affected according to the envelope conditions and especially in the case of C public building where 3 faces of them face envelope, heating load takes up a high percentage compared to total load of atrium area supporting the judgment that the form and size of atrium highly affects energy load.

Table 13. Atrium ratio of Cooling load

	Except Atrium (MWh)	Atrium((MWh)	Ratio(%)	Atrium(%)
A building	379	64	14.5	12.4
B building	83	2	2.1	4.7
C building	74	8	9.4	2.9

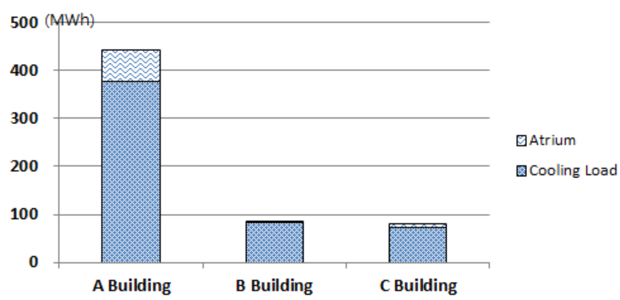


Fig. 6. The ratio of Heating load and Atrium

5. Conclusion

This research analyzed the changes in energy load through simulation to draw basic data for establishment of improvement measure of green building validation program and effectiveness analysis of government guidelines by analyzing air-conditioning load by changes in windows ratio regarding large public buildings with high energy consumption.

First, in the case of glass curtain wall, envelope temperature was shown high more than 5℃ at least and 10℃ at maximum as a result of measurement of thermo-graphic camera showing high heat gain due to windows and doors thus it was judged that the use of glass with low heat resistance highly affects energy consumption increase. This research was conducted only in summer but it is thought features of thermal distribution because of higher windows by meausring heat loss in winter.

For windows ratio, we could check energy load decreases in the same way of prior researches as a result of reducing windows ratio 60% to 50%, 40%. But large public buildings newly built recently have atriums thereby causing difficulty in change application of plan and facade. Thus, we analyzed energy load separating the atrium as other building parts and it was shown that atrium takes up a higher percentage in energy load than general parts. This is the part not considered in guideline about windows ratio and the part that atrium takes up in actual energy load was shown higher at least two times in the case of heating load than the area ratio. Although heating load was shown low rather, it was judged load increases according to the effect and form of direction and envelope. Thus, atrium is a space of disadvantages in energy consumption even if differences exist by form and size and this should be considered. The proposal of energy saving guideline that recommends changes in windows ratio simply has its limitations. Thus the way to reduce the load that atrium takes up by plan should be applied to the guideline.

Although glass curtain wall are used very much due to its various features such as visiblity, symbol for communication and sunlight, it is obvious that it is disadvantageous envelope plan in energy consumption aspect. While obeying to design guideline, it is considered more researches on how energy load burden and ratio in large space composed of only glasses like atrium are proposed in guideline will be needed. Besides, expectations of energy usage based on energy load related to windows ratio is thought to be needed upon evaluation of energy efficiency in green building validation. Through this, energy reduction and efficiency evaluation that reflects building plan will be possible in energy efficiency evaluation based on machine facility.

This research intends to propose clear, precise basic data towards direction of improvement and correction of green building validation program by analyzing energy load according to the features such as curtain wall ratio, direction and size of atrium in plan aspect in the future.

Acknowledgement

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References

[1] Keith elder Envelop Building, 2000.
[2] Kim, Yong-Sik, "What is Green Building", 2012
[3] Shin, Sung-Woo, "Green Building Performance Evaluation and Design Technology", 2007
[4] Ko, Dong-Hwan, " A Study on Building Energy Efficiency Requirements of LEED 2009 (Version 3.0) and Korea Green Building Rating System : Analysis and Comparison of Energy Saving and Annual Consumption", Journal of Architectural Institute of Korea, Vol.26, No.5, 2009
[5] Kim, Kyeong-A, Kim, Bongl-Joo, "Heat Loss the Case Study of Office Building", The Korea Institute of Building Construction, Vol.11, No.1, 2011
[6] Kim, Chang-Nam, Kim, Il-Ho, "A study on the reduction performance of building energy demand according to the ration of window area". Korea Institute of Ecological Architecture and Environment Vol.20, 2011
[7] Park, Seoung-Kil, Yoo,Ho-Chun, "Optimal and economic window areaof office buildings regarding energy efficiency", journal of Architectural Institute of Korea Vol.25, No.1, 2005
[8] Jang, Cheol-Yong, Han, Hye-Sim, Lee, Jin-Sook, "The Building Energy Rating Evaluation of Middle Region Apartment depending on window area ratio, Korea Institute of Architectural sustainable environment and Building systems, 2010
[9] Jang, Cheol-Yong, Han, Hye-Sim, Lee, Jin-Sook, "The Building Energy Efficiency Rating Evaluation of Apartment depending on SC and Window area ratio", The Korean Solar Energy Society Vol.30, No.5, 2010
[10] Cho, Jin-Hwan, Chung, Kwang-Seop, Kim, Young-Il, Kim, Sung-Min, "Air-conditioning load analysis and energy basic unit assessment of window area ratio of office building", Society of Air-Conditioning and refrigerating engineers of Korea, 2012
[11] Kim, Nan-Jung, "A Case Analysis on Effect of Thermal Environment in Atrium on Building Energy Consumption(Focus on Window Area Ratio), Konkuk Univ. master's thesis, 2014