Energy Performance Evaluation of an Atrium by Applying Various Window Conditions

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ABSTRACT

Recently, supplying glass space like atrium is being extended widely for introducing natural light into a building, improving rest room functions and having a pleasant work environment. However, some problems can occur in atrium such as overheating and excessive vertical temperature difference during the summer time, making people feel unpleasant and increase air conditioning load.

This study targets that the air conditioning load according to characteristics of the atrium's various windows can be expected through building energy performance evaluation analysis. Esp-r was used for simulation to evaluate air conditioning energy load. A building, which is located in Seoul, was selected for evaluating energy performance and modeling. The analysis model was divided into the main building and Atrium. Window 5.0 was used to acquire optical datum which put into Esp-r construction data base.

As a simulation result, 1) Blue Low-e window decreased load 25% is most effective for reducing energy load.

2) Solar radiation at each direction, eastern and roof have relatively high, southern and northern were not big.

3) Eastern and roof surface had the remarkable temperature increase during cooling period as increasing cooling energy load.

1. INTRODUCTION

Outdoor space role is essential to improve urban people's living qualities such as being healthy and living in comfort. Lately, supplying glass space like Atrium is being extended widely for introducing natural light into building, improving rest room function and having a pleasant work environment.

Atrium makes people gather, making up atmosphere like outdoor square and increases building's added value by supplying a pleasant environment to building users. Also, Atrium's big glass makes people feel visually open and presents a harmonized atmosphere with outdoor space through gardens and big glass.

However, if only the pleasant feeling by the Atrium's optical opening is focused, vigorous temperature overheated situation and excessive temperature difference can occur in summer time, making people feel unpleasant and increasing air conditioning load.

Up to now, Study (1), (2) for measuring high and low temperature in Atrium space have been implemented, it was showed that the higher it is, the bigger high and low temperature difference is. Also, study (3), thermo-environment performance evaluation by using CFD analysis, expected the likely problems in Atrium and suggested the solutions by analyzing air temperature and flow. But studies on energy performance evaluation for the inside thermo-environment control and energy saving engineering in big space are insufficient. This study targets that the air conditioning load according to characteristics of the Atrium's various windows can be expected through buildings energy performance evaluation (ESP-r) analysis.

2. Outline and Method of Simulation

2.1 Target Building

A building, which is located in Seoul, was selected for evaluating energy performance. An atrium is in eastern part of the building and serves as lobby inviting to the public and friendly to its users. The atrium is 21.85m in height, 504 m^2 in area. The shape is elongated rectangle oriented east. The atrium space is indirectly cooling/heating by Air Handling Unit. Outline of the building is as Table 1 and Figure 1, 2 show the building site plan and view.

Table 1: Outline of the Building

Location	Jongno 3 Ga ,Jongno-gu, Seoul
Purpose	Business, Sale, Living Facility
Building Size	Basement 1st - 4 th: Parking lot, Machine Room, Sales Facility Ground floor 1st - 22th : Business and Living Facility Ground floor 23 th - 24th: Machine Room
Structure	Steel framed reinforced Concrete Structure, Reinforced Concrete Structure
Height	97.20m
External Finish	T6 Reflection Glass, PC Tile finished
Land Area	10,246 m^2
Construction Area	3,867.77 m^2
Outline of Atrium	Type: Open Area: 504 m^2 Height: 21.85m Window: THK 34 Laminated Glass + THK 24 Clear Double Glass Cooling/ Heating: AHU

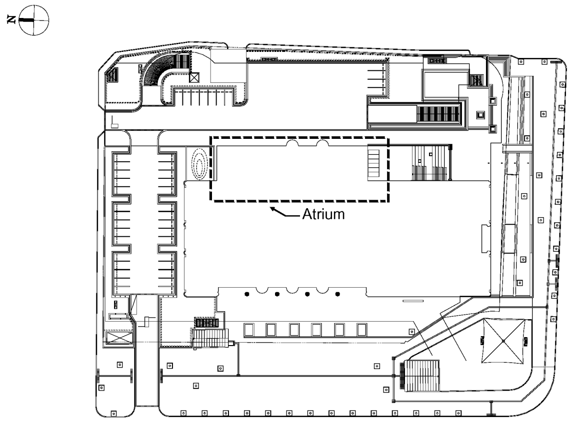

Figure 1: Building Site Plan

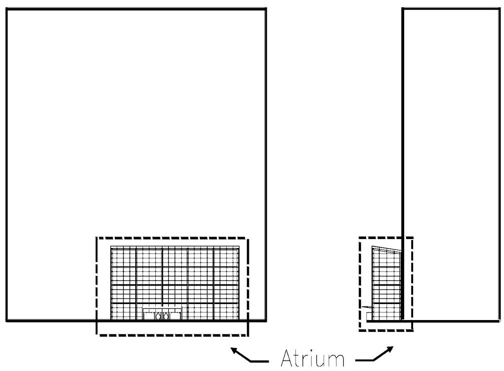

Figure 2: Rear and Side View

2.2 Esp-r Simulation

This study uses Esp-r simulation tool, which was developed by the European Community through the European Reference Building Simulation Program. This program is for accurate building energy performance evaluation and treats the building and plant as an integrated, dynamic system.

2.2.1 Outline of Modeling

The analysis model was divided into the main building and Atrium. The Atrium was divided into southern, eastern, northern, roof and middle zone.
Among them, the main building was exempted and only Atrium 5 zones were targeted. Modeling space was length 45m, width 11.2m, height 20.95m, being simplified as possible.

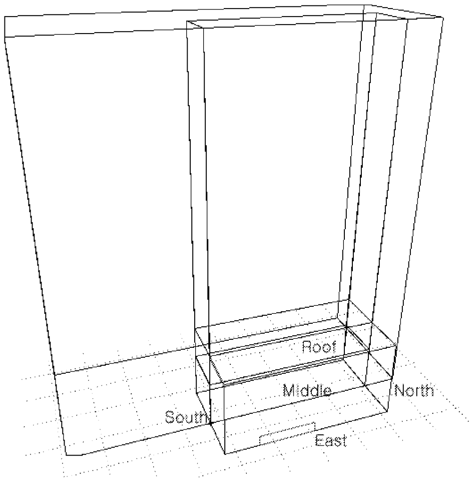

Figure 3: Modeling Shape

2.2.2 Weather data

Weather data is set to Seoul in 2007, Site Longitude difference is degrees from some local reference meridian, (east: +, west: -) for Glasgow relative to the Greenwich meridian.
Simulation duration is from Jan. 1 to Dec. 31 and Table 2 shows input weather data and geographical location. .

Table 2: Geography and Weather Conditions

Input Item	Value
Region	Seoul
Site Latitude	37.4°
Longitude	-8.5° E
Simulation Duration	01/01 12/31

2.2.3 Schedule of casual gain

In order to consider the inside load change according to occupants, lights and equipments, building use schedule was calculated on the basis of the Ministry of Knowledge Economy Report(5). Daily using time was fixed as 09:00 18:00 and air conditioning 07:00 18:00. Unit for heating source is as follow.
The human body was fixed as people number per unit area, light W per unit area and instrument as none. Main items and fixing conditions in building use and air conditioning are like Table 3, 4.

Table 3: Schedule of Casual Gain

Casual gain Type	Period	Amount of Heat
Occupant (m²/person)	09:00 18:00 (Weekdays)	10
Light (W/m²)		15 20
Equipment (W/m²)		-
Infiltration + Ventilation (m³/Person)	00:00 24:00	25

Table 4: Schedule of Air Handling Unit

Air Handling Unit	Control Period	Set Point
Heating	07:00 18:00 (Weekdays)	20°C
Cooling		26°C

2.3 Window 5.0 simulation

Window 5.0 was used to acquire optical datum which put into Esp-r construction data base.

2.3.1 Outline of the program

Window 5.0 developed by LBNL in USA was used as a window performance evaluation program. This program can calculate not only the thermo-flow rate under the ASHRAE standard condition but also the window optical data on SHGC, Tsol and Tvis at each incidence angle. Now, most complex buildings' thermo-performance programs accept Window analysis results as a window performance input data.(4)

2.3.2 Result of Window optical performance analysis

In this study 6 kinds of windows, which are widely applied to atrium and building envelope: Clear, Green, Blue, Clear Low-e, Green Low-e, Blue Low-e, were selected
Glass optical performance analysis was implemented, and SHGC, Tsol and SC at each incidence angle are calculated to know the exact solar radiation quantity.

Table 5: Optical Properties and Construction of 6 kinds of Windows

Window Type	Construction (mm)	Visible Transmission	Solar Reflectance	Solar Absorption	U-value
CL Double	6CL+12A+6CL	0.792	0.117	0.147	2.787
GN Double	6GN+12A+6CL	0.669	0.079	0.450	2.787
BL Double	6BL+12A+6CL	0.517	0.068	0.509	2.787
CL Low-e	6CL+12A+6CL-LE	0.687	0.208	0.163	1.742
GN Low-e	6CL+12A+6GN-LE	0.580	0.116	0.482	1.742
BL Low-e	6CL+12A+6BL-LE	0.448	0.098	0.542	1.742

CL:Clear Plate, BL:Blue Plate, GN:Green Plate, CL-LE: Clear low-e, BL-LE: Blue low-e, GN-LE: Green low-e A: Air

Quantitative Tsol data according to the window type at each incident angle was showed in Table5. Blue Low-e was the highest in visible transmission and solar Reflectance, however the highest in Absorption. Such optical characteristics will be used as a correct data in Esp-r simulation.

3. Results

3.1 Cooling/heating energy load change according to windows.

Figure 4 shows the cooling/heating energy load change according to 6 kinds of windows.. Heating energy load decreased 7%, 2 % in Clear Low-e, Blue Low-e respectively comparing to Clear window, but increased 3 % in Green, Blue. Cooling energy decreased load was Blue Low-e, Green Low-e, Blue, Green, Clear Low-e in order and decreased max. 23% (Blue Low-e) and min. 6% (Clear Low-e)

3.2 Variation of Solar Radiation according to windows

Figure 5, 6 show solar radiation comparison acquired through Atrium. Compared targets were Clear and Blue Low-e that have the biggest air conditioning energy load difference and compared time was Jan. 17 and Aug. 17

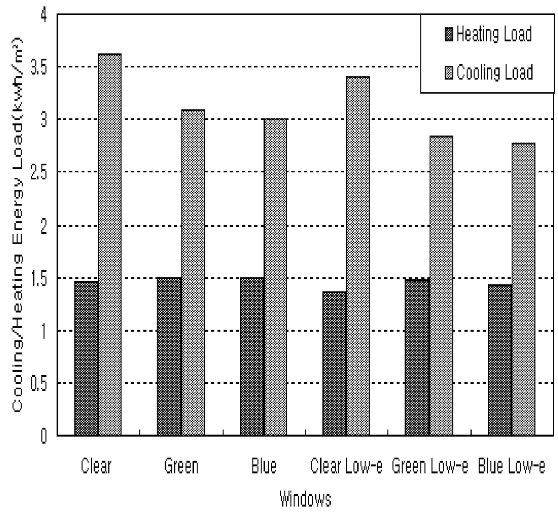

Figure 4: Cooling/heating energy load

when max. cooling/heating energy load is occurred. In Aug. 17, total solar radiation difference at each direction was eastern direction 187kW, roof 142kW, southern direction 49kW and northern 36kW. Eastern and roof, which have relatively high difference, showed 38% and 31% solar radiation decrease.
In Jan. 17, total solar radiation difference at each direction was eastern direction 76kW, roof 59kW, southern direction 41kW, northern direction 59kW. Solar radiation was not big compared to Aug.17, but solar radiation difference order at each direction had the same trend.

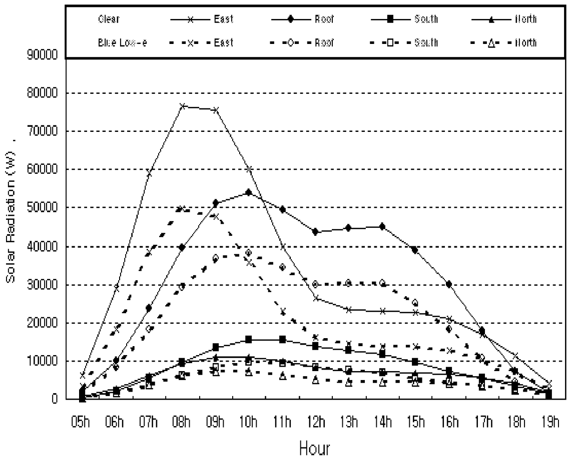

Figure 5: Variation of Solar Radiation on Aug. 17

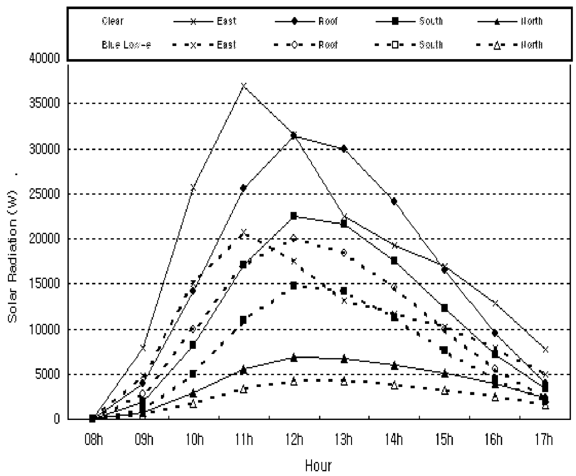

Figure 6: Variation of Solar Radiation on Jan. 17

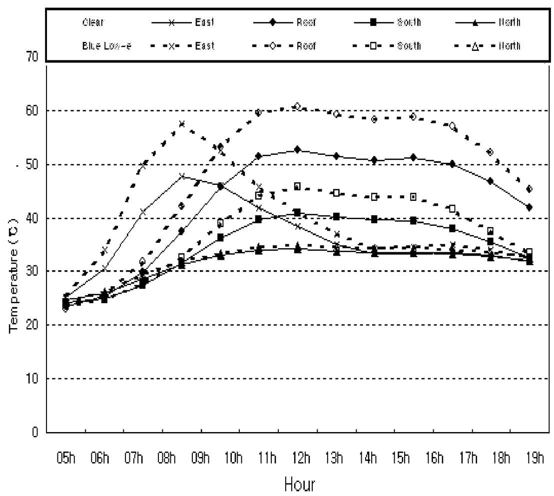

Figure 7: Temperature Variation of Inside Window Surface on Aug. 17

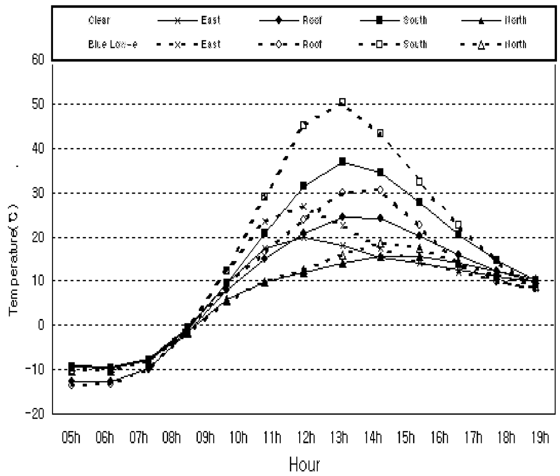

Figure 8: Temperature Variation of Inside Window Surface on Jan 17

3.3 Temperature Variation of Inside window Surface

Figure 7, 8 show temperature difference during 05:30 ~ 17: 30 when the temperature variation on Atrium inside window surface is high. Compared target and time are the same as solar radiation. The result in Aug 17 is as below . In case of eastern surface, CL window had min. 25.33 and max. 46.08°C in widow surface temperature, and BL Low-e had min. 25.27°C (05:30) and max. 52.73°C (08:30) increasing max. 6°C. In case of roof surface, the highest temperature occurred at 11:30, Clear’s was 52.68°C, BL Lowe’s was 60.75°C showing 8°C difference. Southern and northern surfaces had similar temperature patterns and differences.
In Jan. 17 , southern surface had the remarkable temperature increase as a result of temperature difference analysis, and in case of northern face there was not big difference.

4. CONCLUSIONS

This study implemented buildings energy performance evaluation according to characteristics of Atrium’s various windows and analyzed the air conditioning load, solar radiation temperature inside surface. The following conclusions can be made:

1) The result of cooling/heating energy load analysis according to 6 kinds of windows, Blue Low-e window decreased load 25% is most effective for reducing energy load. It verifies that energy load could greatly be reduced by changing window.

2) Solar radiation at each direction, eastern and roof have relatively high, southern and northern were not big. It is more desirable that windows need to be selected in each direction depending on solar radiation.

3) Eastern and roof surface had the remarkable temperature increase during cooling period as increasing cooling energy load. It is expected that energy load could be reduced by increasing window's adiabatic efficiency.

It is thought that not only the outside surface but also the ventilation via openings can have a big influence in the Atrium. But this study did not consider ventilation via openings. Therefore, it is necessary to have a ventilation plan suitable for winter, summer and intermediate periods maintaining inside air quality by using natural air as much as possible. Study for optimum ventilation strategy will be tried next time.

ACKNOWLEDGEMENTS

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REFERENCE

1. *Han, Kum-Young (2004). A Measuring Study for the Vertical Temperature Difference in Atria,* Journal of the Architectural Institute of Korea, v.20 n.1 : pp. 187 - 195
2. *Kim, Young-Chul (2004). An Experimental Study on the Thermal Environment in Four-Sided Atrium during Summer Season,* Journal of the Architectural Institute of Korea, v.20 n.6 :pp. 223 - 231
3. *Choi, Dong-Hee(2004). A study on the Improvement of Thermal Environment by planning openings in Atrium, Proceedings of Academic Conference, the Korean Solar Energy Society, n.5 : pp.175 – 181*
4. *An, Young-Sub (2006). Thermal Performance Evaluation of High Performance Window System Applied for the Extended Balcony of a Apartment Building, Proceedings of Academic Conference, Korea Institute of Ecological Architecture and Environment, v.6 n.2 : pp 167 - 173*
5. *Ministry of Knowledge Economy (2007). The Study of Development of Energy Performance Assessment and Policy in Buildings.*
6. *Lee, Chang-Soo (2005). The Comparison of Energy Consumption for the Dry Hydronic Ondol and the Double Floor Hydronic Ondol, Proceedings of Academic Conference,* Architectural Institute of Korea, v.25 n.1 :pp. 275 - 278
7. *Saxon. Richard (1994). Atrium Buildings (Development and Design): Kimoondang*