

A Research on Necessity of Variable G-Value Window(Eco Vario System) in Temperate Climate

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ABSTRACT

The climate is one of the most important environmental elements appearing the attribute of a region in architecture. For example, in a cold climate, heat loss has been the most important problem, so that the shape of an igloo and the minimizing of opening area are a reasonable counterplan. In contrast, in an arid or a tropical climate, heat gain has been the most critical problem, so that the deep eaves, the improvement of the ventilation efficiency, and the maximization of cooling effects by thermal mass are counterplans. On the other hand, in a temperate climate, because cooling and heating problems exist simultaneously, heat loss is critical in winter and heat gain is an important problem in summer to solve.

The method presenting these relationships is by the heat transmission coefficient (U-value) and energy transmission coefficient (G-value). In a cold climate, U-value should be minimized and G-value maximized, while in an arid or a tropical climate U-value as well as G-value should be lower. It is because in an arid or a tropical climate solar radiation is so high. On the other hand, in a temperate climate, G-value should be minimized in summer, while G-value should be maximized and U-value lower in winter.

Especially, the curtain wall system with wide glass is applied to domestic super-high buildings. In most super-high buildings, interior blinds which make high heat gains in interim term were applied so that several problems, such as wintergarden effects and comfortable degeneracy, are generated seriously. For this reason, buildings in a temperate climate have strong needs to use the variable G-Value window system to correspond to the seasonable physical differences. In this sense, it is necessary to mention the variable G-value window in the temperate climate. Such variety is the base of Eco Vario System or buildings to understand buildings in the temperate climate where annual climate characteristics are obvious.

KEYWORDS: Eco Vario, G-value, intelligent, smart, energy

1. INTRODUCTION – climate and Vario

Building is the most ideal indicator of the climatic characteristics of the region. Buildings all around the world reflect the regional climatic conditions, and it is possible to understand how

2. Local Eco Vario system

Understanding Eco Vario Building aiming to integrate the ecological variety starts from understanding of the local climatic conditions. Looking at the map of the world, the climatic regions consist of frigid, temperate, dry and tropical regions. The frigid climate is shown in Siberia and Greenland where the monthly average lowest temperature holds on lower than -15 °C, the dry climate in North Africa, Arab and the Southern part of the US where the monthly average highest temperature holds on higher than 25°C, and the tropical climate in India, Middle Africa and Amazon areas where the monthly average temperature 20°C over a month with over 80% of relative humidity. The temperate climate is presented in north- und Middle Europe, the Northern part of the US and Korea where the monthly average temperature lies between -15 ~ +25 °C. In particular, comparison of the monthly average temperature difference between Seoul and Berlin, Germany indicates the largest amplitude of Berlin is only 19.2K while that of Seoul extends to 28.3K. As a result, Seoul is much colder in the winter but incomparably hot in the summer than Berlin. In other words, even though these two cities fall into the same temperate climate region, their local characteristics are significantly different. In this sense, it is unreasonable to expect Seoul to have the same results as Eco Vario Building strategies applied in Berlin.

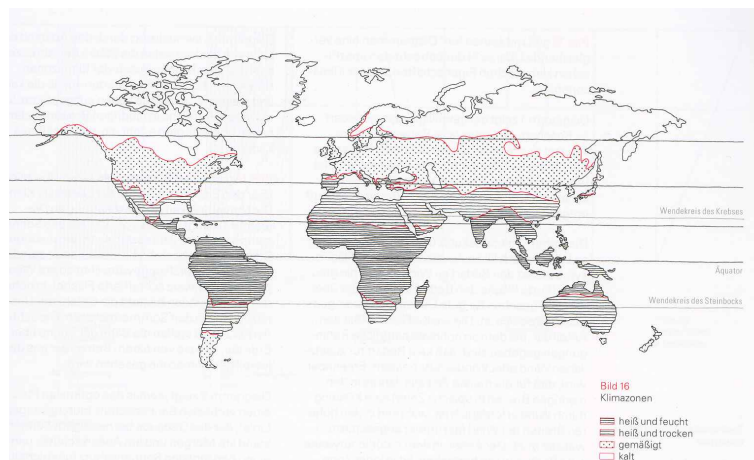


Figure4. Regulation on Climatic Regions according to DIN(Deutsches Institut for Normung)

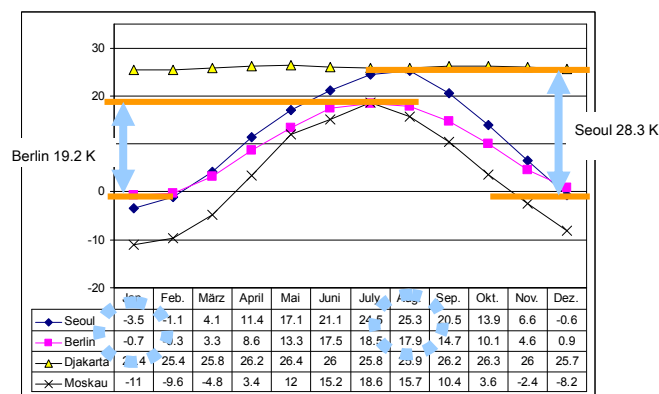


Figure5. Comparison of Monthly Average Temperature of Cities

3. The Core of Eco Vario – Building Exterior

To understand most easily, buildings in the cold areas show the characteristic of the buildings in the cold areas while those in the hot areas show that of the hot areas, and those in areas

where are cold and hot show the characteristics of the two climate areas at the same time. However, if environmental surroundings have only one characteristic whether hot or cold, the role of Eco Vario is relatively easy as long as efforts to overcome the environmental limits are made. On the other hand, if two characteristics are presented at the same time, it is very complicated to set up a counterplan. Taking an example, human beings put on or take off clothes according to surroundings such as the amount of sunshine. Even if there are number of people working in one same office, those who feel the surrounding warm are lightly dressed, while those feel the surrounding cold are heavily dressed. Therefore, people with various sensitivity can cope with the external surroundings through clothing, but is it possible for buildings as well? Straightforwardly saying, it is impossible to control the climatic conditions through building exteriors like human beings control the external surroundings through clothing.

Particularly, building exteriors play the most important role in realization of Eco Vario buildings because it is building exterior that plays a role as clothes in human beings as it connects the surroundings to the interior and it is where the exterior and the interior meet. Therefore, the role of Eco Vario buildings to execute the objectives is more significant in the temperate climatic regions where the both extremes need to be overcome.

4. Eco Vario due to Manhattanization

Let's approach to the concept of such Eco Vario through situations of Korea. In Korea, the building manhattanization problem occurred in 70 ~ 80s along with economic growth. In the late 90s, super-high office buildings started appearing and in the end, recently, apartment houses such as apartment & stores buildings of more than 50 stories were built. The physical characteristic that most of super-high buildings had increased glass sides as a result of application of the Curtain Wall construction method. In particular, ultimately super-high buildings caused the wintergarden effect as there is no obstacle around blocking the inflow of sunrays to the super-high buildings, the inflow of sunrays sharply increased, the opening areas of windows were reduced to keep safety from wind pressure, and they were built with core type structure of which rears are closed.

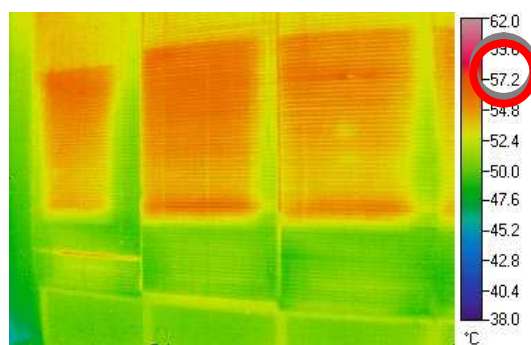


Figure6. Window-side Interior Thermal Infrared Image in the Single Exterior Cooling period

The traditional building in the past started planning with the ultimate concept of Eco Vario, however, in today's super-high buildings, it is difficult to find Eco Vario. If such super-high buildings fail to realize Eco Vario, not only the building's energy consumption increases by geometric progression but also the occupants in the buildings will feel uncomfortable. Human beings feel comfortable at 18~27°C and 35~65% of relative humidity, and beyond or below such ranges they feel increasingly discomfort. Particularly, to keep such range of comfortable surroundings in the super-high building with many glass sides, it takes lots of energy, and the

dependency on air conditioning increases, which results in increase of discomfort of actual residents.

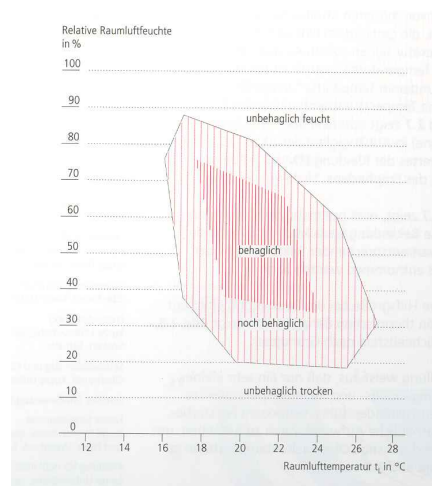


Figure7. Comfort Range of Human Beings

5. Variable G-value: the Most Important Technical Measure to Determine Eco Vario in Temperate Climate

The indicators which can most simply indicate the physical characteristics of ordinary buildings with large glassed sides are the heat transmission coefficient (U-value) and energy transmission coefficient (G-value, relative heat gain). These two values are important indicators to determine Eco Vario, and especially G-value is the most important indicator to determine Eco Vario in designing (buildings with large glassed sides) in the temperate climate the heat transmission coefficient (U-value) indicates the movement heat according to temperate differences per unit area, which has a significance for heating periods and the lower this value is, the more favorable it is. The energy transmission coefficient (G-value) indicates the inflow of sunrays and requires a large value as it needs to obtain the maximum solar heat in the heating period; on the other hand, as solar heat needs to be obtained for cooling periods, the value needs to be low. Therefore, low U-value and high G-value need to be applied in the frigid climate while low U-value and low G-value need to be applied in the tropical climate in order to achieve the ideal heat management by the building exterior as Eco Vario. However, in the temperate climate like Korea has, as there are clearly distinguished heating and cooling periods, it is necessary to set up active strategies for Eco Vario requiring diversely applicable U-value and G-value in each season. As a result, it is necessary to provide low U-value and high G-value for a heating period and low U-value and low G-value for a cooling period. But, it is very restrictive to give variable functions to the building once glasses and blinds were installed as they have their own physical characteristics. For example, by applying internal blinds to triple low-e glasses, the heating energy is saved as U-value is low but the cooling energy is not saved as much since energy transmission coefficient (G-value) is not changed; therefore, it is difficult to expect to save cooling energy. Applying reflective glasses or film layers to reduce the inflow of sunrays may enable a cooling period to reduce the volume of incoming sunrays, which is advantageous; however, on the contrary, reduction of incoming sunrays to a heating period causes rise of heating load so heating energy consumption increases and additional artificial lighting is required as the interior illuminance gets lower, therefore such physical choice is wrongful from the Eco Vario view. Thus, under the housing circumstances of the country where seasonal characteristics are obvious and buildings may be exposed to a high level of

wind pressure due to development by high buildings, it is absolutely required to establish a system in terms of Eco Vario.

$$K = \frac{1}{\Sigma R} = \frac{1}{\frac{1}{\alpha_o} + \Sigma \frac{d}{k} + \frac{1}{\alpha_i}} \text{ (kcal/m}^2\text{h}^\circ\text{C or W/m}^2\text{K)}$$

Figure8. Heat Transmission Coefficient Formula

G-VALUE : $g = \tau + q_i$

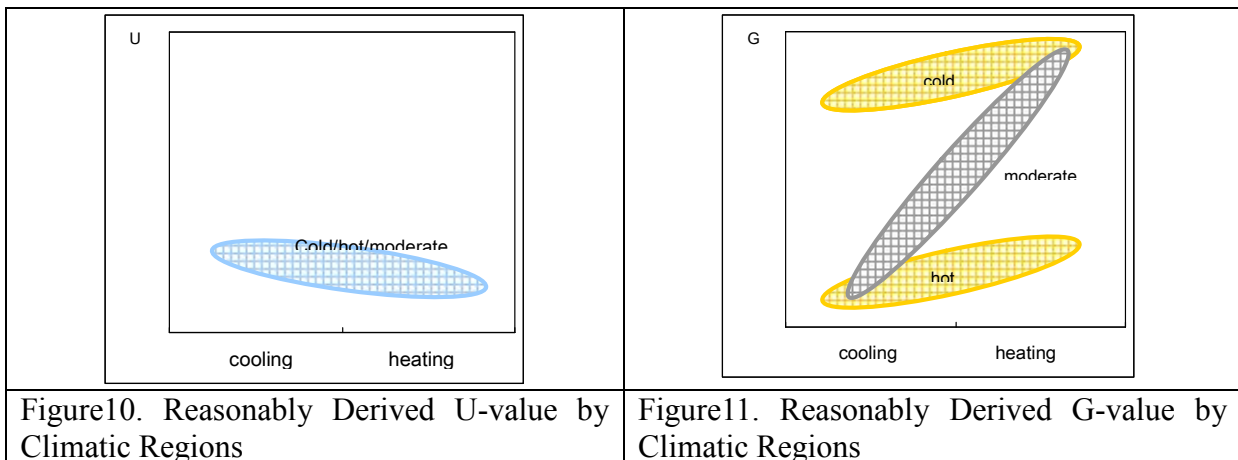
$$\tau = \frac{\sum_{\lambda=300nm}^{2500nm} S_{\lambda} \tau(\lambda) \Delta\lambda}{\sum_{\lambda=300nm}^{2500nm} S_{\lambda} \Delta\lambda}$$

$$q_i = \frac{\left(\frac{\alpha_{e1} + \alpha_{e2}}{h_e} + \frac{\alpha_{e2}}{\Lambda} \right)}{\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{\Lambda}}$$

$$\alpha_{e1} = \frac{\sum_{\lambda=300nm}^{2500nm} S_{\lambda} \left[\alpha_1(\lambda) + \frac{\alpha_1(\lambda) \tau_1(\lambda) \rho_2(\lambda)}{1 - \rho_1(\lambda) \rho_2(\lambda)} \right] \Delta\lambda}{\sum_{\lambda=300nm}^{2500nm} S_{\lambda} \Delta\lambda}$$

$$\alpha_{e2} = \frac{\sum_{\lambda=300nm}^{2500nm} S_{\lambda} \left[\frac{\alpha_2(\lambda) \tau_2(\lambda)}{1 - \rho_1(\lambda) \rho_2(\lambda)} \right] \Delta\lambda}{\sum_{\lambda=300nm}^{2500nm} S_{\lambda} \Delta\lambda}$$

Figure9. G-value Formula DIN EN 410



6. Eco Vario variable G-value Window : Double Façade System

According to Energy Saving Design Standard for Building (Ministry of Construction & Transportation's Notice No. 2004-459, Dec. 31, 2004), heat transmission coefficient of windows in the central area was 3.84W/m² K, which is much higher than 0.47W/m² K of that of exterior walls. Therefore, windows of buildings are thermally the weakest part. In relation to it, recently in the developed countries, they have developed and put to practical use of the windows of which the heat transmission coefficient is around 0.8W/m² K as a counterplan for losses of heat through windows. The heat transmission coefficient of the duplex low-e glass window which is commonly used for high buildings in Korea is around 1.5~1.8 W/m²K, and as mostly internal blinds are used because external blinds are limited to use due to climatic restrictions, its energy transmission coefficient is judged to be around 0.6~0.7. Consequently, such choice will not influence on the heating period, but it will cause serious physical problems during cooling period and interim. Thus, variable G-value window is required as a counterplan to overcome the physical restrictions of super-high glassed buildings. Such counterplan is the duplex exterior in which blinds functioning as external blinds are installed in the air space by

installing two interior and exterior windows. The most significant characteristic of Double Façade System lies in Vario. Double Façade System in which the ordinary exterior windows consists of heat strengthened glasses and the interior windows consist of the insulated glasses can change the heat transmission coefficient to $1.2\sim 1.5 \text{ W/m}^2\text{K}$ depending on the method of opening and shutting as well as the energy transmission coefficient can be variable at over 0.15 during the cooling period and at over 0.6 during the heating period. Therefore, as human beings actively overcome the external surroundings by changing clothes, through Eco Vario System, buildings can overcome the external physical surroundings through the building exterior, and it's truly one of the Eco Vario Systems.

6. Test Results

6.1 Establishment of experimental room and Test Equipment

Experimental room 1 and experimental room 2 ($4.5\text{m(w)} \times 4.5\text{m(d)} \times 2.7\text{m(h)}$) were built up in Korea Institute of Construction Technology located in Ilsan-gu, Goyang-shi, and the existing single exterior and Double Façade System were installed to analyze the cooling and heating energy saving effects and the tendency of natural ventilation. Each experimental room was equipped with floor heating panels and a separate air conditioner, and their consumed energy is respectively managed in PC through the electricity consumption gauge. Figure is the extensive view of experimental room and the plan of duplex exterior applied.

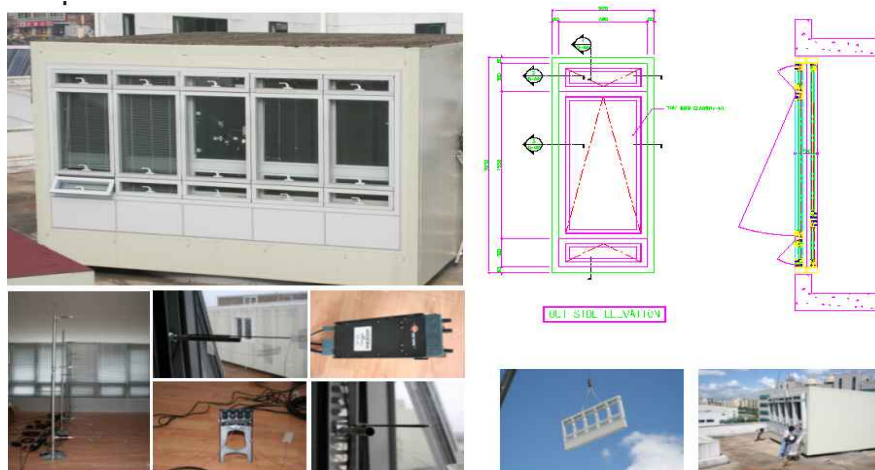


Figure12. Extensive view of experimental room and Double Exterior Plan

6.2 Cooling Energy Consumption Measurement -

By operating the cooling system for 32 days from August 9 to September 14, 2006, cooling energy consumption of experimental room was compared and analyzed. Interior temperature was set at 26°C which is the cooling system interior appropriate temperature according to Energy Saving Design Standard for Building and the machine was set to be operated at 28°C and suspended at 24°C considering operating efficiency. Blinds were kept at 80° , close to vertical. Analysis on cooling energy consumption shows that the energy saving rate of Double Façade System reaches around 67% as the duplex exterior consumes around $42\text{kWh/day}(2\text{kWh/m}^2\text{day})$ and single exterior consumes $130\text{kWh/day}(6\text{kWh/m}^2\text{day})$. Such results came out as the pent roof installed in the air space of the duplex exterior blocks the

inflow of the direct solar radiation and reduced 0.15 comparing to 0.7 of G-value of the single exterior.

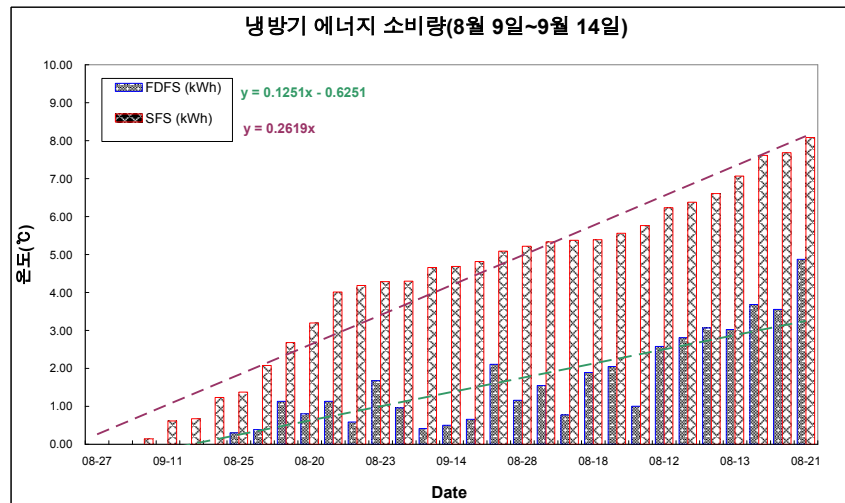


Figure 13. Analysis Results on Energy Consumption during Cooling Period

6.3 Heating Energy Consumption Analysis during Natural Ventilation

Heating energy consumption was analyzed under the circumstances where one same-sized window of each laboratory was opened tilted, pent roofs were not operated and the natural ventilation occurred from 9 am to 18 pm for 15 days from January 20 to February 9, 2007. The temperature was set and maintained at 20°C as the heating period interior appropriate temperature. With the window shut, loss of heat occurs due to transmission and infiltration and loss of heat by the natural ventilation increases when applying the natural ventilation through the open window. As a result of the heating operation for 15 days, 389.1kWh of energy was consumed in a single exterior and 333.5kWh was consumed in a duplex exterior, therefore overall about 14.3% of the heating energy was reduced.²

²Actually in apartment houses, the flake-type contacts the front and rear side or the tower-type contacts the outer space in all sides. Therefore, the average heat transmission coefficient has a great influence on the heat transmission coefficient of the glassed sides. However, as the whole 6 sides of this chamber were exposed to the outer air, the heat transmission coefficient of the glassed sides has little effect on the average heat transmission coefficient. Thus, the experimental results showed about 14% of reduction of the heating energy consumption but about 25% of reduction effect is expected in the actual apartment houses as shown in the simulation results.

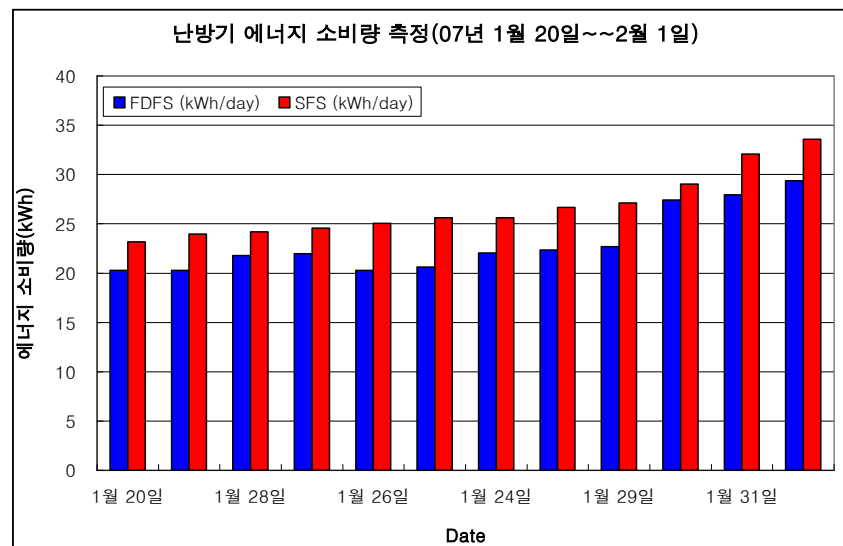


Figure 14. Analysis Results of Energy Consumption during Heating Period

7. Conclusion

It is not easy to manage reasonably the energy through the building exterior according to Eco Vario in the temperate climatic regions. For the building with large glassed areas, it is not wise to choose the internal blinds as serious damages during interim and cooling period due to high G-value even if solar radiation can be reasonably used as high G-value can be obtained during the heating period by high heat acquisition around the year. In addition, if the external blinds are selected, low G-value during interim and the cooling period is obtained, which is physically favorable; however as long as it is operated during the heating period, the heating energy consumption increases as the flow of sunrays decreases. In this case, additional blinds are required for reasonable energy management. In Germany, already a number of buildings wisely manage through ‘Aussenliegender Sonnenschutz and Innenliegender Blendschutz.’ However, it is not convenient to put to practical use of the external blinds in Korea. Therefore, it is necessary to apply Double Façade System as the applicable Eco Vario strategy for the climatic conditions of Korea is G-value variable Window because the duplex window functions blinds during the cooling period and reduces G-value. And during the heating period, by not operating blinds, high G-value can be aimed and variable U-value is enabled as the duplex glass effect is achieved during the cooling period and the triple glass effect is achieved during the heating period. Such relationship was diagrammed in the Figure below. It is judged that Double Façade System will play a significant role as an applicable Eco Vario concept especially to the glassed buildings in the temperate climatic regions in the future.

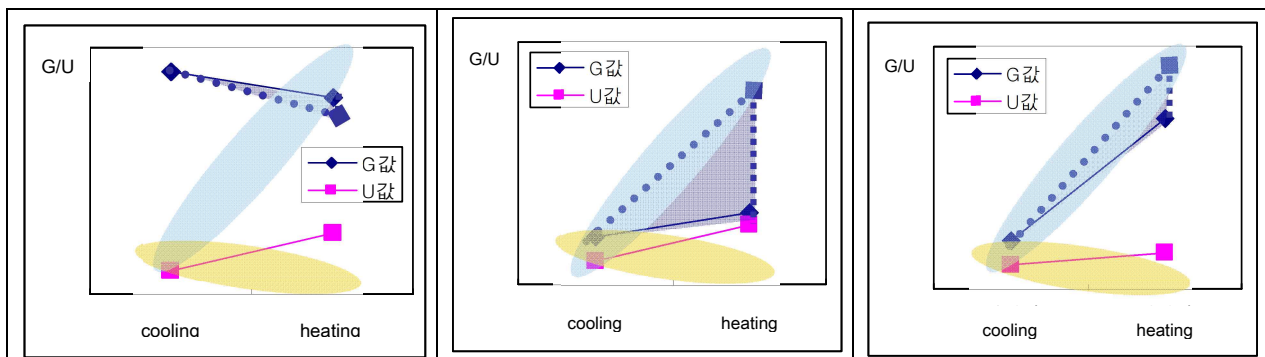
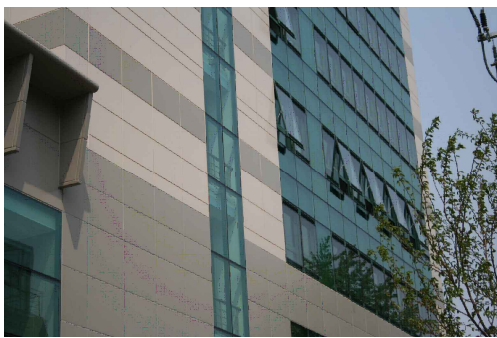


Figure15. Heat Management Tendency in case of Application of the Internal Blinds in the Temperate Climatic Regions	Figure 16. Heat Management Tendency in case of Application of the External Blinds in the Temperate Climatic Regions	Figure 17. Heat Management Tendency in case of Application of Double Façade System in the Temperate Climatic Region
		
Figure18. Nation's First Compact Double Façade System, Caroline Building in Apgujeong, 2007/03	Figure 19. Compact Double Façade System applied in Seoul Greens Office at Boramae Park, 2007/11	

8. Reference

1. H. Kim, K. Lee, D. Jang, S. Moon, Development of Multi-Functional Skin for Green Building, Korea Institute of Construction of Technology, Goyang , 2003~2007
2. K. Lee, H. Kim, Y. Yoon, D. Jang, The FDFS (Functional Double Façade System) development for Reduction of Cooling / Heating energy consumption and reinforcement of natural ventilation, Korea Institute of Construction of Technology, Goyang, 2006
3. Keonho Lee, Untersuchungen zur Einsatzmöglichkeit von Doppelfassaden bei hohen Verwaltungsbauten mit Glasfassaden im extremgemäßigten Klimagebiet, Berlin, 2003
4. Klaus Daniels, Low-Tech, Light-Tech, High-Tech, Berlin, 2000
5. Oesterle, Doppelschalige Fassaden, ganzheitliche Planung, Muenchen, 1999
6. K. Lee, C. Park, C. Choi, D. Jang, a Comparative Experimental Study on Thermal Performance of Box-typed Double Skin and Curtain Wall, SB07, Seoul, 2007
7. DIN 4108-3 Teil 3: Klimabedingter Feuchteschutz, Anforderungen, Berechnungsverfahren und Hinweise fuer Planung und Ausfuehrung, Waermeschutz und Energie-Einsparung un Gebaeuden, 2002
8. DIN EN 410, Glas im Bauwesen – Bestimmung der lichttechnischen und Strahlungsphysikalischen Kenngrößen von Verglasungen,
9. KS L 2514, Testing method on transmittance, reflectance and emittance of flat glasses and evaluation of solar heat gain coefficient, 2004