

Energy-efficient glazing choosing for high-rise apartments in Korea

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ABSTRACT: The rapid economic development and the high population densities of South Korea have built a number of high-rise apartment buildings. The increase in electricity consumption by residential sector, particularly in summer month, has been caused by the growing demand for air-conditioning systems to provide comfort for the occupants. Korea government has given a progressive tax in electric charges. Some units in high-rise apartment consumes 1700kWh in July and electric charges reaches up to 800,000won (800dollar)

This paper describes an investigation of the effect of glazing type on both the summer required cooling energy and electric charges on high-rise apartment building in Pusan, Korea

Keywords: High-rise apartments, DOE-2.2, Cooling loads, Electric consumption

1. INTRODUCTION

1.1 Object of Study

After 1970s, Several oil shocks stirred up Crisis consciousness of energy problem around world. Specially, The fact that the above of 1/3 in whole energy consumption of the most nation is relating with the building has been changing architecture system. The main object of architectural design is improvement of building energy performance is becoming the main objet of building design

In Korea, high electric consumption is new problem in tower-type apartment, which is using curtain wall system. Some units in high-rise apartment

consumes 1700kWh in July and electric charges reaches up to 800,000 won.

It is very important to choosing energy efficient window system in high-rise apartment have high window ratio. So, this study suggests method of choosing energy-efficient window system using energy simulation program in the design development.

1.2 Method of study

Detailed building energy simulations haver been carries out using the computer program WINDOW and eQuest. It was decided to select a high-rise apartment under construction in Pusan, Korea rather than creating a generic design.

2. Estimating method of cooling and heating charges

2.1 Estimating method of cooling charges

Cooling fee was estimated with electric consumption of air conditioning system and ventilation system. Electric charges of high-rise apartment in Korea was composed of electric consumption in units and in common areas. In this case electric consumption in units was estimated.

In Korea, as the graduated tax is applied in electric charges, it is necessary to estimate electric consumption except air conditioning system and ventilation system to estimate cooling charges. For this purpose the data in Survey on Electricity consumption characteristics of home appliances(2006.12), which was surveyed by every year, was used. Units have areas of 118.8~168.3m² consumes 338.2kWh and Units have over 168.3m² consumes 345.2kWh(Table III)

2.2 Estimating method of heating charges

LNG(Liquefied Natural Gas) for home application is used for cooking, heating(~12m³), heating(over 12m³), and central heating

Table I : Basic electric charges in multifamily

Basic electric charges (won/unit)	
Under 100kWh	370
100 ~ 200kWh	820
201 ~ 300kWh	1,430
301 ~ 400kWh	3,420
401 ~ 500kWh	6,410
Over 500kWh	11,750

Table II : Consumted electirc charges in multifamily

Consumted electricity charges (won/kWh)	
To next 100kWh	55.10
To next 100kWh	113.80
To next 100kWh	168.30
To next 100kWh	248.60
To next 100kWh	366.40
Over 500kWh	643.90

Table III: Average monthly electricity consumption

Areas(m2)	Average monthly electricity consumption (kWh)
Uner 33	175.8
36.3 ~ 49.5	215.0
52.8 ~ 66.0	245.1
69.3 ~ 82.5	269.3
85.8 ~ 99.0	308.3
102.3 ~ 115.5	314.7
118.8 ~ 165.0	338.2
Over 51	345.3

Table IV: LNG charges

	basic charges	Consumted Charges (m ³ /won)
COOKING	750	621.12
Heating (~12m ³)	750	621.12
Heating (Over 12m ³)	750	685.71
Central Heating	-	675.28

3. The BASECASE model

3.1 BASE model

Typical floor have 10units and core area.(Figure 1). The units was simplified having one thermal zone(Figure 2), three floors of total 64 floor buildings was modeled for saving computer simulation time. and results of mid floor which

have no roof and floor effect was Analyzes.

Figure 3 shows modeling results.



Figure 1: Typical floor plane drawing.

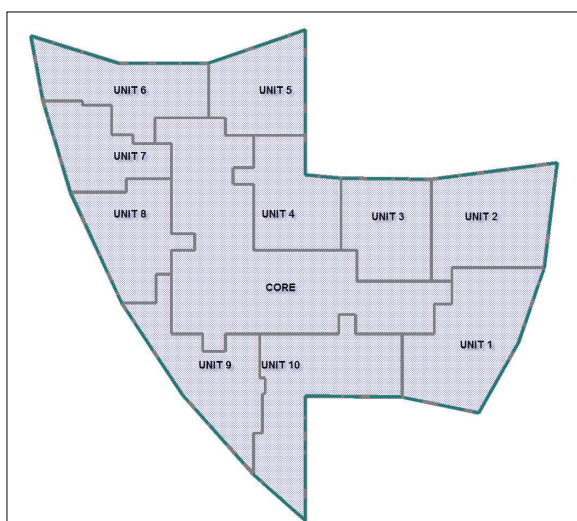


Figure 2: Simplified typical floor

3.2 Properties of windows and construction

3.2.1 Properties of window

The properties of window is very important in high-rise building having high ratio of widow. The basecase model use double reflective low-e window, which is composing of 6mm reflective low-e window, 12mm air gap and 6mm clear glass and table 6 shows the properties of glass which composes double reflective low-e window.

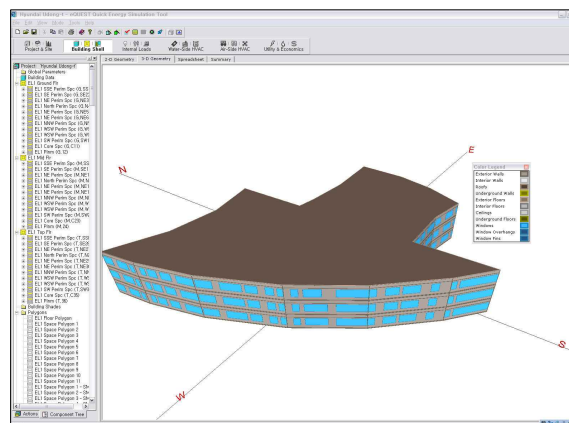


Figure 3: Basemodel modeling result

Table V: Area and volume of units

	Area (m ²)	Flr-To-Ceil (m)	Volume (m ³)
UNIT1	164.7	2.5	411.8
UNIT2	142.5	2.5	356.3
UNIT3	86.2	2.5	215.5
UNIT4	124.6	2.5	311.5
UNIT5	95.3	2.5	238.3
UNIT6	118.2	2.5	295.5
UNIT7	106.2	2.5	265.5
UNIT8	122.2	2.5	305.5
UNIT9	131.5	2.5	328.8
UNIT10	173.8	2.5	434.5

The properties of this window is calculated using WINDOW (figure 4). the table VI shows the calculated property of 24mm reflective low-e window

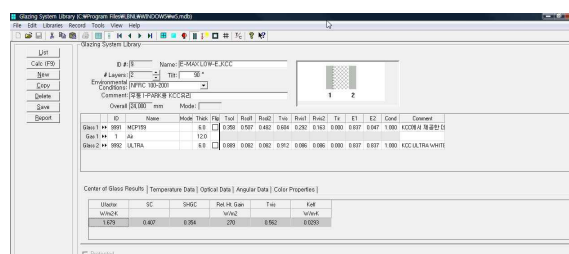


Figure 4 WINDOW PROGRAM

Table VI: The properties of glass

		Low-e	Clear
Think(mm)		6	6
Transmissivity	Visible	0.604	0.912
	Solar	0.358	0.889
Reflectivity	Visiable	1#	0.292
		2#	0.086
	Solar	1#	0.507
		2#	0.482
emissivity	1#	0.837	0.837
	2#	0.047	0.837
Thermal Conductivity		1.0	1.0

Table VII: The properties of double reflective low-e window

Thermal conductance ($\text{w/m}^2\text{°C}$)	1.679
Shading Coefficient	0.407
Solar Heating Gain Coefficient (W/m^2)	0.354
Relative Heative Gain	270
Transmissivity of visibility	0.562

3.2.2 The property of External wall

The external wall is composite of curtain wall and the thermal conductance was calculated in 0.45w/m^2

3.2.3 Internal heat gain

Building Internal heat gain is composite of Occupancy heat gain, lighting heat gain, and equipment heat gain. All values used are ones in ASHRAE STANDARD 90.1.

4. Heating and Cooling load

4.1 Annual heating and cooling load

Annual heating and cooling load of 30units modeled are analyzed. Annual cooling load and heating loads are calculated in relatively 281,168kWh and -87.863kWh Cooling load is greater than heating load 3.2 times.

4.2 Composites of heating and cooling laod

The most important factor in heating load is radiation and the later is internal heat gain. The most important factor in cooling load is heat loss through window and infiltration heat loss

To reduce annual heatina and cooling load, it is necessary to reduce thermal conductnace of window and to low shading coefficient.

Table VIII: The composition and thermal conductance of exteral wall

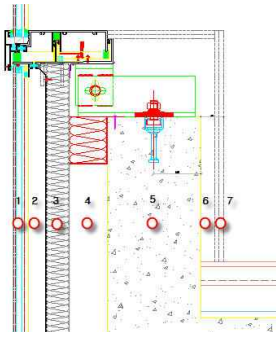
	Layers	Thermal Conductivity ($\text{w/m}^2\text{°C}$)	Thickness (mm)	Thermal ($\text{m}^2\text{°C/W}$)	Specific heat ($\text{kJ/kg}^{\circ}\text{C}$)	밀도 (kg/m^3)
	Outside film.	-	-	0.030	-	-
	1 Spandrel galss	-	24	0.270	-	-
	2 Air gap	-	45	0.160	-	-
	3 Insulation	0.043	50	1.163	837	10
	4 Air gap	-	80	0.160	-	-
	5 Concrete	1.310	200	0.153	837	2243
	6 Air gap	-	30	0.160	-	-
	7 Finish material	0.819	18	0.022	837	1682
	Inside film	-	-	0.120	-	-
Thermal Conductance : $0.45\text{W/m}^2\text{°C}$						

Table VIII: Annual cooling and heating load of 30units

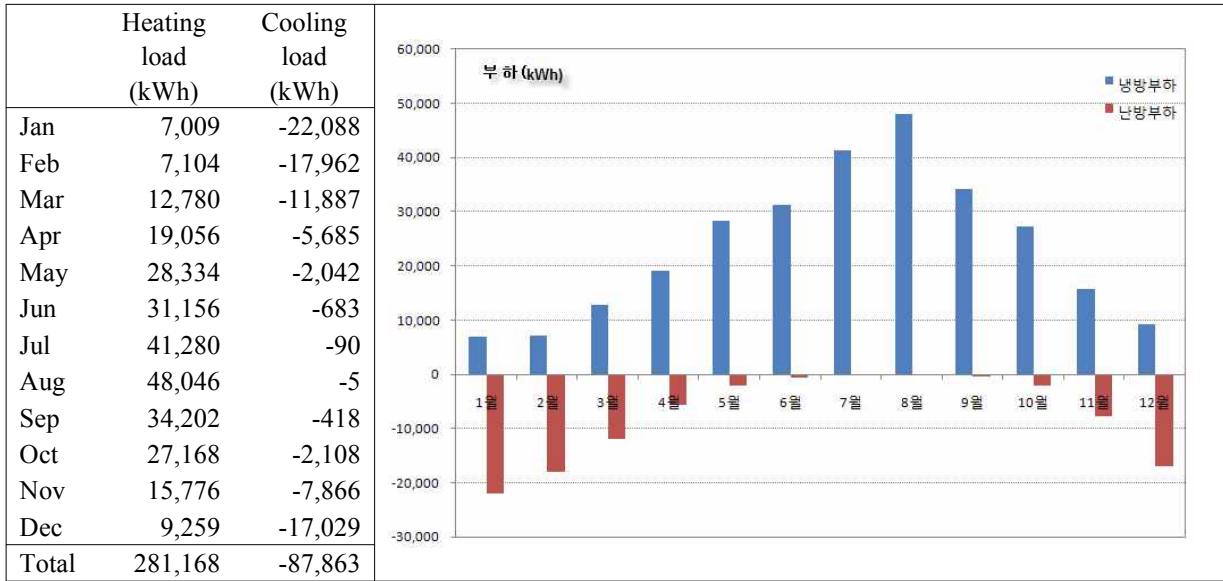


Table IX Annual heating and cooling components of 30units

	Heating load (kWh)			Cooling load (kWh)
	Sensible load	Latent load	Total	
Exteranl Conductae	-11,217	0	-11,217	-37,412
Infilation	-3,779	40,304	36,525	-52,063
Window Conductance	6,067	0	6,067	-53,351
Window Radiation	100,158	0	100,158	9,036
Occupancy	37,855	24,764	62,619	12,608
Internal lighting	47,059	0	47,059	8,939
Internal equipment	105,033	0	105,033	24,383
Total	281,176	65,068	346,244	-87,861

5. Heating and cooling charges of units

5.1 Cooling charges of units

Calculated cooling lowest charges and highest charges are relatively 726,430won and 1,375,535won. The highest cooling charge units is unit 10. The highest cooling charges of units 5 is 3,575won/m²-yr and the lowest cooling charges of unit 7 is 2,736won/m²-yr So the highest one has more charges than the lowest by 31%

5.2 Heating charges of units

Caluated heating charges are between 110,303 and 411,520won. The highest one (unit 4) has more charges than the lowest one(unit 9) by 97%

Table X: Monthly cooling charges of units

	Area (m ²)	Jun (won)	Jul (won)	Aug (won)	Sep (won)	Oct (won)	Per areas (won/m ²)
UNIT 1	412	71,070	377,830	634,070	233,590	1,316,972	3,198
UNIT 2	356	43,180	320,720	542,550	197,730	1,104,536	3,100
UNIT 3	216	34,090	241,650	410,770	143,540	830,266	3,853
UNIT 4	312	31,360	237,250	423,950	136,960	829,832	2,664
UNIT 5	238	39,540	247,510	413,700	150,870	851,858	3,575
UNIT 6	296	40,450	284,110	477,390	160,380	962,626	3,258
UNIT 7	266	31,970	213,830	363,180	117,190	726,436	2,736
UNIT 8	306	34,090	245,310	424,680	132,570	836,956	2,740
UNIT 9	329	39,540	289,240	491,300	150,870	971,279	2,954
UNIT 10	435	74,720	395,390	669,930	235,060	1,375,535	3,166

Table XI: Monthly heating charges of units

	Area (m ²)	Jan (won)	Feb (won)	Mar (won)	Nov (won)	Dec (won)	Total (won)	Per area (won)
UNIT 1	412	91,952	77,974	52,174	28,412	69,263	319,775	776
UNIT 2	356	97,337	66,189	43,217	23,571	59,345	289,659	814
UNIT 3	216	34,004	27,968	16,600	7,343	24,388	110,303	511
UNIT 4	312	47,113	40,623	27,316	11,967	34,306	161,325	517
UNIT 5	238	63,069	52,173	34,061	19,310	47,541	216,154	908
UNIT 6	296	84,482	69,253	45,302	26,055	65,093	290,185	980
UNIT 7	266	55,128	46,063	30,344	15,303	41,830	188,667	709
UNIT 8	306	68,672	57,377	38,666	20,307	52,836	237,858	777
UNIT 9	329	95,035	78,881	53,334	30,461	74,412	332,123	1009
UNIT 10	435	117,228	98,608	67,296	38,529	89,860	411,520	946

6. Cooling and heating charges with different widow

6.1 Simulation case

The most important factors in heating and cooling load of high-rise apartments are radiation and heat loss through window. So Heating and cooling charges are predicted with different windows.

Applied widows are

- (1) 24mm tint double glass
- (2) 24mm tint low-e double glass (#3 coating)
- (3) 24mm tint low-e double glass (#2 coating)
- (4) 24mm low reflective double glass
- (5) 24mm reflective Low-e glass

Table XII shows the properties of window applied.

6.2 Cooling charges with different window

In the case of using tint double glass, the cooling charges is similar using reflective double low-e glass. But the cooling charges with low-e(#3 coating) and low-e(#2 coating) are higher than with basecase (reflective low-e glass) relatively by 24% and 19% and the cooling charges with reflective low-e window is lower than basecase by 4%

Table XII: The properties of window

경로 사항	24MM 알루미늄복합유리	24MM 알루미늄 LOW-e 복합유리(1)	24MM 알루미늄 LOW-e 복합유리(2)	24MM 저반사복합유리	24MM 반사 코팅 복합유리 (외부코팅 + 반사)
개념					
유리부품 구성	6BL+12A+6CL	6CL+12A+6EVI161	6ECI161+12A+6CL	6BDR342+12A+6CL	6MCP161+12A+6CL
가시광선	투과율	51%	71%	53%	54%
	반사율	0%	12%	16%	14%
열전달 계수	2.69W/㎡K	1.75W/㎡K	1.76W/㎡K	2.69W/㎡K	1.66W/㎡K
차폐 계수	0.52	0.64	0.47	0.44	0.39
자외선 차단율(dB)	33	33	33	33	33
특성	색상	Blueish	CLEAR	LIGHT BLUE	BLUE
	단열성능	단열성능 취약	단열성능 우수	단열성능 우수, 차폐성능 우수	단열성능 취약 / 차폐성능 우수
	기타사항	저렴한 가격	1. 무영광 색상 2. 차폐성능 떨어짐	1. 우수한 단열성능 2. 편광 요구에 따른 광투과율 가능(색상)	1. 우수 단열성능 2. 편광 요구에 따른 광투과율 가능(색상)

Table XIII: The cooling and heating charges with different window

		Color tint double window	low-E double (#3 coating)	low-E double (#2 coating)	low reflective double	Reflective low-e
Typical Units (10units)	Cooling Charges	9,961,663	12,719,313	12,082,373	9,352,803	9,806,293
	Heating Charges	3,355,533	2,122,711	2,260,141	3,495,475	2,557,569
	Total	13,317,196	14,842,024	14,342,514	12,848,278	12,363,862
Average Unit	Cooling Charges	996,166	1,271,931	1,208,237	935,280	980,629
	Heating Charges	335,553	212,271	226,014	349,548	255,757
	Total	1,331,720	1,484,202	1,434,251	1,284,828	1,236,386
Rate		107.7%	120.0%	116.0%	103.9%	100.0%

6.3 Heating charges with different window

The heating charges with Low-e double window(#3 coating) are lower than basecase by 17%. But the heating charges with low reflective window are higher than basecase by 36.7% for lower solar radiation through window.

6.4 Heating and cooling charges with different window.

The annual heating and cooling charges of units are predicted using previously calculated heating and cooling charges.

In the case of reflective low-e window the cooling and heating charges is

lowest. It is lower than with low-e window(#3 coating) by 20%

7. Results

The results can be summarized as following.

(1) The most important factor of cooling of high-rise building in PUSAN, Korea is solar radiation through window and the that of heating is heat loss through window

(2) Cooling charges of each units is between 2,736won/m²-yr and 3,575 won/m²-yr. Heating charges of each units is between 511won/m²-yr and 1,009won/m²-yr. Average Cooling charges

is higher than heating charges by 2.96times

(3) Using reflective double glass lower cooling charges by 4% and using low-e glass(#3 coating) lower heating chages by 20%

(4) Considering both heating and coolin charges. reflective double are lowest cooling and heating charges and is lower than low-e(#3 coating) by 20%

Though the result of this study is on the individual case, The most energy effective glass can be choosing in the design development phase using this method.

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