

A Study of Economizer Cycle Control for Cooling Load Reduction in High-rise Residential Buildings

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ABSTRACT: Recently, high-rise residential buildings are increased due to residence development and maximizes of estate development efficient on hub of cites in Korea. In environment and design aspects, the upper levels of high-rise residential buildings have been restricted window to open and shut and high-rise residential buildings most has curtain wall envelope which is planed open and close areas of window to character of relative insufficient window area on outdoor walls. It improves insulation performance to reduce cooling and heating load that airtight disposition due to former motive is increased. However, Relative insufficient window areas for ventilation fall off in indoor air quality. Also, chemical substances of indoor finish materials are reported to emit volatile organic compound, formaldehyde and occupants activities frequently make troubles in connection with CO₂, dust, odor and what not. Energy management methods are required cooling and heating load to minimize with preservation of indoor air quality through economizer cycle control from pollutants.

Keywords: Economizer cycle, cooling load reduction, High-rise residential building, Ventilation performance, Cooling load management

NOMENCLATURE

$v(h)$: wind speed in height 'h' meters

$v(10)$: wind speed in height 10
(reference wind)

α : roughness coefficient due to obstacle
(building, tree., etc)

1. INTRODUCTION

Today, high-rise residential buildings are increased due to residence development. In cases of high-rise residential buildings, they can maximize of estate development efficient, however external environment change that can be generated by wind velocity and increasing daylight caused by

height, irregularity of loads., etc which cause energy anti-conspicuous consumption. Besides, expanded window areas for daylight and view has been increasing cooling load due to overheat in the summer.

Recently, balcony expansion also legalized in the country and it can be increasing maintenance in cooling load. The majority of the high-rise residential buildings especially designed cooling system without considering of building features, and have been applied package air-conditioner with using ducts that has been used regular middle and low-raised buildings. In case of ventilation used mechanical system is to inflow into indoor

with air which is minimized. According to the these reasons that have been caused the increase load and excessive cooling cost.

2. RESEARCH METHODOLOGY

This research aims to analyze cooling load through Economizer Cycle Control on indoor ventilation performance and suggests appropriate indoor ventilation performance with design devices for cooling load management.

2.1 Survey proceeding

This research has the following these steps for aims achievement

- 1) To research present status and examples of high-rise residential buildings around the energy performance and to recognize energy performance factors of high-rise residential buildings .
- 2) To design energy analysis modeling based on produced energy performance factors in selected buildings
- 3) To install energy performance factors and factors range after energy simulation and there are procedure of sensitivity analysis though energy simulation.
- 4) To suggest efficient cooling plan in high-rise residential buildings. As a simulation developed IEA, the module of VE(Virtual Environment) which included APACHE when it is used to the thermal environment design and energy simulation.

3. PRESENT STATUS OF HIGH-RISE RESIDENTIAL BUILDINGS

3.1 Domestic trend of the high-rise residential buildings

High-rise residential buildings in the country has been expanded from downtown to near cities according to urbanization and maximization of estate development efficient. In these days, residential and

commercial complex have been built mostly for efficient utilization in the downtown area. It has been increased and raised high in residential buildings due to needs in aspects of the land efficiency, economic feasibility, unit cost of construction in accordance with developed techniques, and generation of the cities

Table I: Synopsis of case study buildings

Category	Case I
Location	Pusan, Korea
Building area(m ²)	41,218
Total floor area(m ²)	56,3056
Structure Scale	RC
Scale(Floor)	5-bldgs, Apt 64F, Hotel 34F, Office 9F, Shopping 3F
Use	Residential use., etc
Unit (Apt., hotel)	Apt.(1,631), Hotel(254), Office, Shopping

3.2 Energy performance research of the selected high-rise residential buildings

It is to present status of the selected high-rise residential buildings in the country and research the energy performance. It is to analyze architecture and equipment of the selected buildings as which were surveyed by research parameters based on energy reduction strategy in relation to high-rise buildings in the preceding studied. Table 1 described synopsis of case study buildings.

4. ENERGY INTERPERTATION MODELING OF THE OBJECT BUILDINGS

4.1 Synopsis of selected case buildings

Case buildings are ‘I’ which are recently constructing by H construction and located

in Pusan is one of the high-density residential area in the country.

Case buildings would consist of six-buildings. The three-buildings of them were planned the high-rise top-type which was



Figure 1: Perspective and Typical floor plan of selected building

formed residence around core. Fig. 1 is perspective and typical floor plan of the former.

4.2 To make out the base model of the case buildings

Table II: Selected residential building synopsis

Category	Case I-residential
Location	Pusan, Korea
Building area(m ²)	41,218
Total floor area(m ²)	56,3056
Structure Scale	RC
Scale(Floor)	Apt64F, B6F

Table III: The base model synopsis

Bldg Direction	Case I-residential
Core type	Central core type
Typical floor area(m ²)	1265.2
Insulation	Exterior wall(50),
Glass type	20mm e-MAX (6MCP159 + 12A + 6CL)

The base model was reflected same design condition of case buildings which have central core in the plan and top-type RC structure in the elevation, and typical plan was distributed eleven zones. This study simulated in 32F because the middle of case building which in the three residential buildings consisted 64-floors. Table 2 is summarized the case building and Table 3 is the base model synopsis.

4.3 Energy simulation conditions

Simulation conditions can be summarized as follows

4.3.1 Weather data

Weather data of Pusan was used SAREK weather data on the assumption that air conditioning period is from April to November except the winter.

Table IV: Temperature and humidity weather data in Pusan

factors	status	Jan	Feb	Mar	Apr	May	Jun
outdoor temp (°C)	max	12.8	14.4	17.2	22.8	27.2	28.3
	aver	3.0	4.5	7.9	13.1	17.2	20.7
	min	-8.9	-6.7	0.0	5.6	9.4	15.6
RH (%)	max	93.4	92.9	94.3	100.0	100.0	100.0
	aver	49.2	55.8	59.7	63.7	70.7	80.6
	min	15.1	19.5	20.3	22.7	24.4	49.1
factors	status	Jul	Aug	Sep	Oct	Nov	Dec
outdoor temp (°C)	max	30.6	32.8	28.3	25.0	22.8	18.9
	aver	23.9	26.1	21.7	16.8	11.0	6.1
	min	18.9	20.0	16.1	8.3	-3.3	-6.7
RH (%)	max	100.0	95.6	100.0	94.0	100.0	100.0
	aver	87.2	77.6	75.5	63.2	57.2	55.7
	min	62.6	51.8	37.8	33.2	23.4	18.3

4.3.2 Indoor set temperature and humidity point

Set temperature and humidity of interior were depended on energy saving design standard. in the summer, DB 26°C and humidity 50% are applied.

4.3.3 Occupants schedules

Occupants in the living space are referred as ASHRAE Handbook Fundamentals 2001 who are decided 4 people.

4.3.4 Lighting and appliances schedules

Lighting and appliances schedules is used $5.43\text{W/m}^2 (0.5\text{W/ft}^2)$ that is residence criterion of ASHRAE STANDARD 90.1 and weights gives consequence to schedule based on ASHRAE STANDARD 90.1.

4.3.5 Internal heat gains

It is referred to occupants heat gain that energy saving plan has been suggested sensible heat 61.6W/people , potential heat 40.7W/people for domestic high-rise residential building. Lighting heat gain when high-efficient fluorescent lamps were applied and installed two lamps in each room is also assumed 3.10W/m^2 . In case of appliances heat gains, they are fixed in the same values of lighting heat which is based on energy saving plan of domestic high-rise residential building.

4.3.6 Envelope conditions

The materials use of the main structure properties in case building is Table V.

Table V: Main structure properties

Category	Material	Thermal conductivity ($\text{W/m}^\circ\text{C}$)	Thick (mm)	Thermal resistance ($\text{m}^2^\circ\text{C/W}$)
Exterior wall	Double glazing	-	24	0.438
	Insulation	0.043	50	1.163
	Con'c	1.310	200	0.153
	Finish	0.819	18	0.022
Ceiling	Wood	0.158	5	0.032
	Light weight con'c	0.130	20	0.000
	Con'c	1.310	250	0.191
	Gypsum board	0.819	10	0.012
Glass	20mm e-Max 6MCP159 + 12A + 6CL) Thermal transmittance($\text{W/m}^2^\circ\text{C}$) : 1.679 Shading coefficient : 0.407			

4.3.7 Wind profile

It is considered wind modification in accordance with this model is high-rise building near 300m. The offered formula can be estimated wind speed when local character and height changes are coming..

$$v(h) = v(10) \cdot \left(\frac{h}{10}\right)^\alpha$$

Table VI: Floor wind changes

	wind speed(m/s)	
	α 0.16	α 0.2
65F	4.2	6
60F	4.1	5.8
55F	4	5.7
50F	4	5.6
45F	3.9	5.4
40F	3.8	5.2
35F	3.8	5
30F	3.7	4.8
25F	3.5	4.5
20F	3.4	4.2
15F	3.3	3.9
10F	3	3.4
5F	2.7	2.7
1F	0	0

1) Floor height 3.2m

Wind speed in Pusan is 4.9m/s in 32F due to considering ground wind speed 2.46m/s , $\alpha = 10\text{m}$, and roughness coefficient 0.2.

5. ENERGY PERFORMANCE ANALYSIS OF THE OBJECT BUILDINGS

5.1 Sensitivity analysis to using energy simulation

5.1.1 Sensitivity analysis summary

Sensitivity analysis is to mean output variable that is followed by input variable and parameter analysis is a synonym for that. In relation to building energy, the input variable is each energy consumption factor and the out variable is energy consumption quantity.

5.1.2 Energy performance parameter for sensitivity analysis

Energy efficient parameters for sensitivity analysis are under the influence of energy performance variable and the other high-rise building features. Their ranges are set real available values based on relative laws. These parameters are simulated between July to September for possibility in sensitivity analysis. The mechanical ventilation minimum value is 0.7ACH according to the government regulations.

Table VI: Energy performance variable and range

Category	Energy performance variable	Variable range
Natural Ventilation	wind	On Off
Mechanical ventilation (dehumidification)	Air change (ACH)	0.7ACH 0.7+1.0ACH 0.7+2.0ACH

5.1.3 Results of sensitivity analysis

1) Natural ventilation

Table VII: Loads caused by Natural ventilation variable

Range	Cooling needs time(h)	Cooling Load (KWh)	Cooling needs ratio(%)	Cooling load ratio(%)
Non-inflow Wind	179	127.6	100	100
On-inflow Wind	348	237.9	194	186

Loads and needs time caused by Natural ventilation variable are Table VII. In Table VII, cooling load is increase when it take into account wind speed. This is looked due to over 80% of humidity in the summer.

2) Mechanical ventilation

Loads and needs time caused by Mechanical ventilation variable are Table VIII. Since the dehumidification, cooling load and time are approximately decreased by mechanical ventilation. This result report possibility of using economizer cycle in the summer. In this study, ventilation is effected on the condition of that interior temperature(DB) is greater than 28°C and exterior temperature is less than 28°C(KEMCO encouragement) and closed when interior temperature is less than 26°C.

Table VIII: Loads caused by Mechanical ventilation variable

Range (ACH)	Cooling needs time(h)	Cooling Load (KWh)	Cooling needs ratio (%)	Cooling load Ratio (%)
0.7	274	375.3	1.0	1.0
0.7+1.0	241	337.6	0.88	0.90
0.7+2.0	219	303.2	0.80	0.81

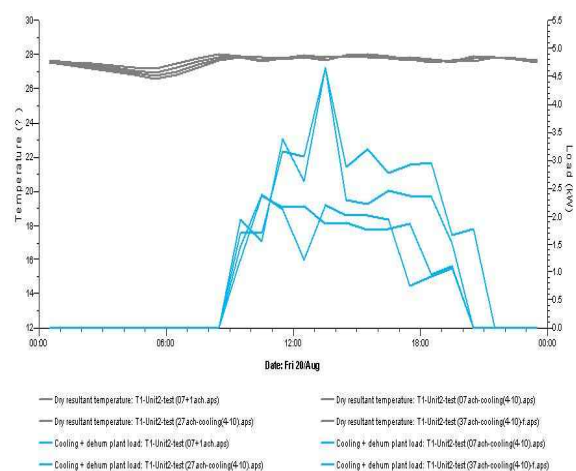
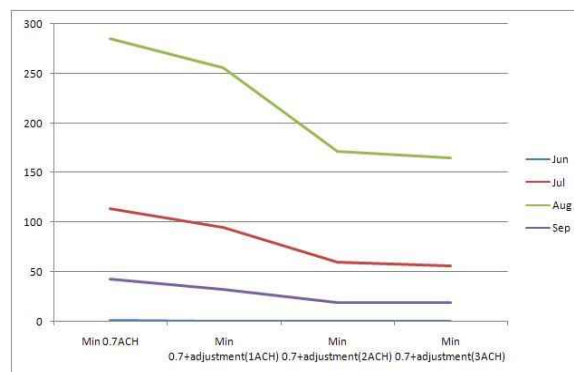
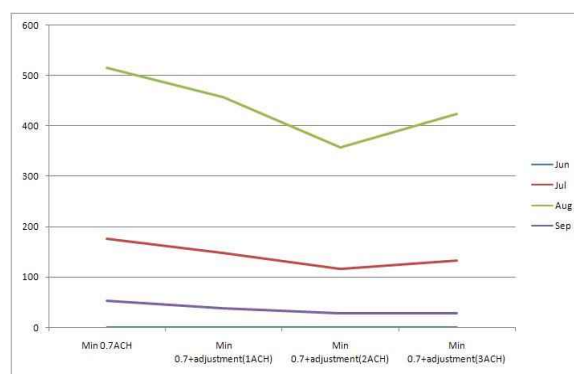
3) The period and air change expansion of Mechanical ventilation

Simulation period is expanded from April to November, and air change is also expanded from 0.7ACH to 0.7+3ACH. As a result, it is presented Table IX that cooling time and load are calculated over 26°C in the summer.

According to Figure 3, cooling time is proportion to air change. However in Figure 4, cooling load is increased 11% in comparison with cooling time is 3% decreased when is over 0.7+2ACH. When they are considered, optimized cooling time and load model is 0.7+2ACH.

Table IX: The period and air change expansion

condition Min 0.7ACH				
category	cooling time		cooling load	
	time(h)	%	load(KWh)	%
Jun	1	0.00	0.1	0.00
Jul	114	100.00	176.9	100.00
Aug	285	100.00	516.2	100.00
Sep	43	100.00	52.3	100.00
avg	443	100.00	745.5	100.00
condition Min 0.7+adjustment(1ACH)				
category	cooling time		cooling load	
	time(h)	%	load(KWh)	%
Jun	0	0.00	0	0.00
Jul	95	83	147.8	84
Aug	256	90	457.6	89
Sep	32	74	37.5	72
avg	383	86	642.8	86
condition Min 0.7+adjustment(2ACH)				
category	cooling time		cooling load	
	time(h)	%	load(KWh)	%
Jun	0.0	0.00	0.0	0.00
Jul	60.0	53	115.7	65
Aug	172.0	60	358.4	69
Sep	19.0	44	27.4	52
avg	251.0	57	501.5	67
condition Min 0.7+adjustment(3ACH)				
category	cooling time		cooling load	
	time(h)	%	load(KWh)	%
Jun	0.0	0.00	0.0	0.00
Jul	56.0	49	131.9	75
Aug	165.0	58	424.9	82
Sep	19.0	44	27.9	53
avg	240.0	54	584.7	78

**Figure 2:** Cooling time and load in case of mechanical ventilation (20, Aug)**Figure 3:** Cooling needs time in case of mechanical ventilation (unit: hr)**Figure 4:** Cooling load in case of mechanical ventilation (unit: KWh)

5.2 Comparison between natural ventilation and mechanical air change

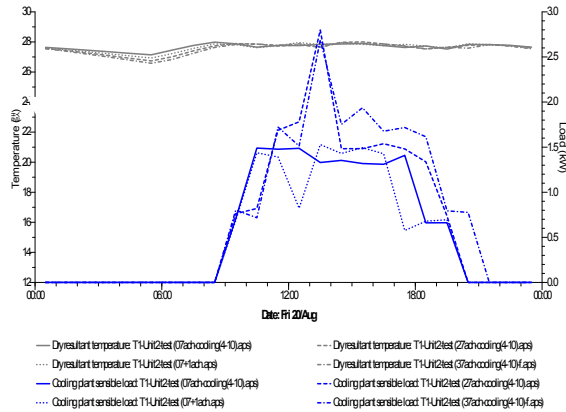


Figure 5: Cooling Sensible load in case of mechanical ventilation (20, Aug)

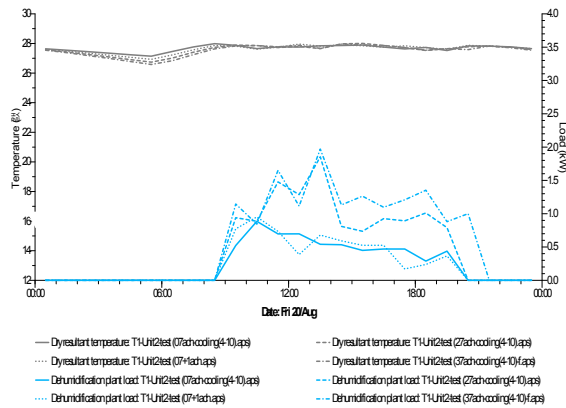


Figure 6: Dehumidification load in case of mechanical ventilation (20, Aug)

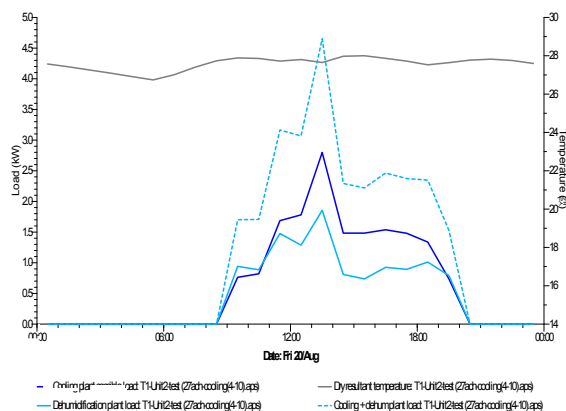


Figure 6: Dehumidification and Cooling Sensible load (0.7+2.0ACH / 20, Aug)

Table X: Cooling Sensible load , Dehumidification load and Total load(June-October)

Range	0.7 (ACH)	0.7+1.0 (ACH)	0.7+2.0 (ACH)	0.7+3.0 (ACH)
Cooling Sensible Load (KWh)	251.3	221.4	267.6	292.2
Dehumidification load (KWh)	124	116.2	233.8	292.6
Sen+Deh load (KWh)	375.3	337.6	501.5	584.8

Table XI: Cooling Sensible load , Dehumidification load and Total load ratio (June-October)

Range	0.7 (ACH)	0.7+1.0 (ACH)	0.7+2.0 (ACH)	0.7+3.0 (ACH)
Cooling Sensible Load	1.0	0.88	1.06	1.16
Dehumidification load	1.0	0.94	1.89	2.36
Sen+Deh load	1.0	0.90	1.34	1.56

Table XII: Comparison between natural ventilation and mechanical air change

Range	Cooling needs time(h)	Cooling Load (KWh)	Cooling needs ratio	Cooling load ratio
NV/On inflow-Wind	348	237.9	1.0	1.0
MV/ 0.7+2.0 ACH	251	501.5	0.72	2.11

Result of Comparison between natural ventilation and mechanical ventilation, mechanical ventilation is greater cooling load 2.11times than natural ventilation, but cooling time is 28% reduction in case of mechanical air change. It is features that is difficult natural ventilation in high-rise residential buildings. Therefore, it is only use of dehumidification and mechanical ventilation in aspect of sensible heat, and the

former can be 28% reduction of cooling load. This result is report to be possibility of economizer cycle in the summer.

6. CONCLUSION

The results can be summarized as following :

- 1) As results of energy simulation in case building which is considered wind speed , height, micro climate, those are reported that natural ventilation has performance of the minimum cooling time, but it is difficult due to the high wind speed of upper zones in case of high-rise residential buildings. Accordingly, 0.7+2.0ACH model with dehumidification is optimized in this study.
- 2) In this study, high-rise buildings without sensible heat cooling can be cooled to reduce cooling load 28% with the dehumidification and air change by economizer cycle in the summer. This result is confirmed possibility of economizer cycle in the summer.

To keep on appropriate indoor ventilation performance through ventilation change rate of Economizer Cycle Control and present integrated cooling and ventilation model for cooling load decrease during the change of season and summer. Also, this research can be reflected in load estimate of high-rise residential buildings later on.

REFERENCES

- [1]Jang-Han, Kim. 2004. A study on the analysis of energy performance of high-rise residential buildings. SAREK winter collection of learned papers. pp739-744. ROK.
- [2]David, Jreijiry. Ahmad, Husaunndee. Christian, Inard. 2007. Numerical study of a hybrid ventilation system for single

family houses. Solar Energy. Vol 81. Pp227-239.

- [3]M, El, Mankibi. F, Cron. P, Michel. C, Inard. 1999. Prediction of hybrid ventilation performance using two simulation tools. Solar Energy. Vol 80. Pp908-926.