

A FEASIBILITY STUDY ON SPACE COOLING WITH OUTDOOR AIR USING A DYNAMIC ENERGY SIMULATION PROGRAM

PART 2: SENSITIVITY ANALYSIS ON FEASIBILITY OF SPACE COOLING WITH OUTDOOR AIR USING DESIGN OF EXPERIMENT

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ABSTRACT

As a series of our research on energy conservation and thermal comfort of detached houses having centralized HVAC systems, sensitivity analysis on feasibility of space cooling with outdoor air was conducted using Design of Experiment(DOE). Effects of varied parameters on building thermal load were examined for five cities such as Tokyo and Osaka that have different weather conditions within the milder climate area of Japan. Building performance(insulation and airtightness performance, solar shading), air conditioning system(setting temperature level, outdoor airflow rate) were selected as the parameters which effect on annual heating load(AHL), annual cooling load(ACL), cooling load during intermediate season(ICL).

The results of the analysis of variance are 1) three parameters (insulation and airtightness performance, solar shading, setting temperature level) except for outdoor airflow rate are significant in AHL in all five cities. 2) all four parameters are significant in ACL in all five cities. 3) solar shading and outdoor airflow rate are significant parameters in ICL in common with all five cities, but some locations show a different tendency in significant parameters which is caused by the difference of climate conditions during intermediate season. 4) solar shading level has an effect on ICL by the interaction with outdoor airflow rate.

KEYWORDS

Sensitivity analysis, Design of Experiment(DOE), Space cooling with outdoor air, Simulation, Centralized HVAC system

INTRODUCTION

In recent years, it is a problem that increase of internal heat sources due to high saturation of electric appliances causes the growth of cooling load in Japan. Under the circumstances, space cooling with outdoor air is said to be one of the potentially energy-efficient methods to solve the problem. Now authors started to research the effects of the method with both experiments and numerical simulation. The purpose of this study is to conduct the comprehensive sensitivity analysis based on results from parametric study in the previous paper. The results of this study are expected to provide fundamental information for the application of the method of space cooling with outdoor air in Japan.

DESCRIPTION OF DOE

Sensitivity analysis was conducted for five cities (Tokyo, Tsujido, Nagoya, Osaka, Fukuoka). In the Japanese residential standard, climatic zones are classified into six zones from I to VI. This analysis is aimed at Zone IV. Climatic conditions are different in five cities even though those belong to Zone

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IV located in milder climate area of Japan.

Factor and level

Table 1 shows the four factors selected as the parameters. Insulation and airtightness performance, solar shading were selected as the two factors for the indices of building performance, and setting temperature level and outdoor airflow rate were selected as the two factors for the indices of air conditioning system. Each factor has three levels as seen in Table 1. Insulation and airtightness performance are prescribed in the Standard and Index for energy conservation in Japanese residences. '1999 standard level' shown in Table 1 is the current standard from Institute for Building Environment and Energy Conservation in September, 2000, and the insulation and airtightness performance was reinforced than '1992 standard level'.

Selection of Latin square

Feasibility of space cooling with outdoor air was evaluated with two different Latin squares (L_{18} and L_{27}). Whether the tendency resulted from each Latin square is similar or not would be confirmed.

- Comparison of cooling load during intermediate season(ICL) in Tokyo between L_{18} and L_{27}
- Examination of the validity of L_{18} for annual heating load(AHL) and annual cooling load(ACL) in Tokyo
- Sensitivity analysis with L_{27} for annual heating load(AHL), annual cooling load(ACL) and cooling load during intermediate season(ICL) in Tokyo and Osaka
- Sensitivity analysis with L_{18} for Annual heating load(AHL), annual cooling load(ACL) and cooling load during intermediate season(ICL) in five cities

Table 1 Factor and level concerning the building performance and air conditioning system (circle: reference)

Factor	Level (from left to right, level 1, level 2, level 3)
P: insulation and airtightness performance	i(R2000 level & $1.0 \text{ cm}^2/\text{m}^2$), (iii)1999 standard level & $2.0 \text{ cm}^2/\text{m}^2$, vi(1992 standard level & $5.0 \text{ cm}^2/\text{m}^2$)
S: solar shading	Lace curtain & solar shading(E), Lace curtain only(C), Nothing(X)
T: setting temperature level	Energy saving(S), Normal(N), Rich (R)
O: outdoor airflow rate	Low(0 ach, L), Middle(2 ach (M)), High(8 ach, H)

ach: air changes per hour

Layout of factors based on DOE

Table 2 and Table 3 show the layout of factors for L_{18} and L_{27} . In L_{27} , the following three interactions were examined:

- 'outdoor airflow rate(O)' and 'insulation and airtightness performance(P)'
- 'outdoor airflow rate(O)' and 'solar shading(S)'
- 'outdoor airflow rate(O)' and 'setting temperature level(T)'

COMPARISON OF WEATHER CONDITIONS FOR FIVE CITIES

Weather condition is one of the important factors which influence on the thermal load. First of all, climatic characteristic for each city was examined in comparison with the weather data. Table 4 shows the statistical data from the Expanded AMeDAS Weather Data (Akasaka et al. 2003) of Tokyo, Tsujido, Nagoya, Osaka, Fukuoka in standard year. It was observed that Nagoya, Tsujido, Osaka, Tokyo, Fukuoka is to be in order of severe climate conditions in terms of heating degree day for the index of heating load. Similarly, it was observed that Osaka, Fukuoka, Tokyo, Nagoya, Tsujido is to be in order of severe climate conditions in terms of cooling degree day for the index of cooling load. On the other hand, climate condition of Nagoya is said to be the severest of five cities and that of Osaka is next, and

it doesn't make much difference among other three cities, in terms of the total of heating degree day and cooling degree day for the index of annual thermal load. It was found that there is not so much difference among four cities except for Tsujido in the number of days for intermediate season, though that for Tsujido is long for 150 days. Therefore, the difference of temperature and solar irradiation would influence the results of thermal load in four cities except for Tsujido. Figure 1 shows the comparison of averaged temperature and transmitted solar irradiation of five cities during each season. As seen in Figure 1, it was found that transmitted solar irradiation of Osaka and Fukuoka is relatively smaller and that of Tsujido and Nagoya is comparatively larger. The annual transmitted solar irradiation was

Table 2 Layout of the four factors to L₁₈

Line No. Experiment No.	1	2 S	3 T	4	5	6	7 O	8 P
1	1	E	S	1	1	1	L	i
2	1	E	N	2	2	2	M	iii
3	1	E	R	3	3	3	H	vi
4	1	C	S	1	2	2	H	vi
5	1	C	N	2	3	3	L	i
6	1	C	R	3	1	1	M	iii
7	1	X	S	2	1	3	M	vi
8	1	X	N	3	2	1	H	i
9	1	X	R	1	3	2	M	iii
10	2	E	S	3	3	2	L	i
11	2	E	N	1	1	3	H	iii
12	2	E	R	2	2	1	L	vi
13	2	C	S	2	3	1	H	iii
14	2	C	N	3	1	2	L	vi
15	2	C	R	1	2	3	M	i
16	2	X	S	3	2	3	L	iii
17	2	X	N	1	3	1	M	vi
18	2	X	R	2	1	2	H	i

Table 3 Layout of the four factors and three interactions to L₂₇

Line No. Experiment No.	1 O	2 S	3 O×S	4 O×S	5 T	6 O×T	7 O×T	8 P	9 O×P	10 O×P	11 e ₁	12 e ₂	13 e ₃
1	L	E	1	1	S	1	1	i	1	1	1	1	1
2	L	E	1	1	N	2	2	iii	2	2	2	2	2
3	L	E	1	1	R	3	3	vi	3	3	3	3	3
4	L	C	2	2	S	1	1	iii	2	2	3	3	3
5	L	C	2	2	N	2	2	vi	3	3	1	1	1
6	L	C	2	2	R	3	3	i	1	1	2	2	2
7	L	X	3	3	S	1	1	vi	3	3	2	2	2
8	L	X	3	3	N	2	2	i	1	1	3	3	3
9	L	X	3	3	R	3	3	iii	2	2	1	1	1
10	M	E	2	3	S	2	3	i	2	3	1	2	3
11	M	E	2	3	N	3	1	iii	3	1	2	3	1
12	M	E	2	3	R	1	2	vi	1	2	3	1	2
13	M	C	3	1	S	2	3	iii	3	1	3	1	2
14	M	C	3	1	N	3	1	vi	1	2	1	2	3
15	M	C	3	1	R	1	2	i	2	3	2	3	1
16	M	X	1	2	S	2	3	vi	1	2	2	3	1
17	M	X	1	2	N	3	1	i	2	3	3	1	2
18	M	X	1	2	R	1	2	iii	3	1	1	2	3
19	H	E	3	2	S	3	2	i	3	2	1	3	2
20	H	E	3	2	N	1	3	iii	1	3	2	1	3
21	H	E	3	2	R	2	1	vi	2	1	3	2	1
22	H	C	1	3	S	3	2	iii	1	3	3	2	1
23	H	C	1	3	N	1	3	vi	2	1	1	3	2
24	H	C	1	3	R	2	1	i	3	2	2	1	3
25	H	X	2	1	S	3	2	vi	2	1	2	1	3
26	H	X	2	1	N	1	3	i	3	2	3	2	1
27	H	X	2	1	R	2	1	iii	1	3	1	3	2

observed to be influenced by the integrated transmitted solar irradiation during heating season. Additionally, it was found that the transmitted solar irradiation during both cooling season and intermediate season vary in each city. Tsujido was found to have smaller transmitted solar irradiation during cooling season and larger during intermediate season compared to the other four cities. The averaged temperature during cooling season was found to be lower in Nagoya than the other four cities.

Table 4 Statistical data from the Expanded AMeDAS Weather Data of five cities in standard year

Weather parameter	Tokyo	Tsujido	Nagoya	Osaka	Fukuoka
Annual averaged temperature(°C)	16.1	14.8	15.6	16.4	16.5
Annual temperature difference(°C) (Maximum- Minimum)	20.6 (26.9-6.3)	20.0 (25.4-5.4)	22.4 (27.7-5.3)	22.1 (27.9-5.8)	21.3 (27.4-6.1)
Heating degree day HDD14-10(Kday)	764.4	899.1	1,004.5	802.7	697.7
Cooling degree day CDD24-24(Kday)	231.9	76.8	198.8	259.0	256.4
HDD14-10 + CDD24-24(Kday)	996.3	975.9	1,203.3	1,061.7	953.4
Annual averaged humidity ratio(g/kg [*])	8.4	8.7	8.5	8.5	9.4
The number of days for heating season(day)	158	164	156	155	151
The number of days for cooling season(day)	69	51	75	80	80
The number of days for intermediate season(day)	138	150	134	130	134
solar altitude on the summer solstice(°)	77.8	78.2	78.3	78.8	79.9
solar altitude on the winter solstice(°)	30.8	31.2	31.3	31.8	32.9
Annual integrated horizontal global solar irradiation(GJ/m ²)	4.36	4.73	5.00	4.70	4.93
Annual prominent wind direction(-)	NNW	NNE	NNW	N	N
Annual averaged wind velocity (m/s at MSL 6.5m)	1.9	1.5	2.3	1.9	2.2

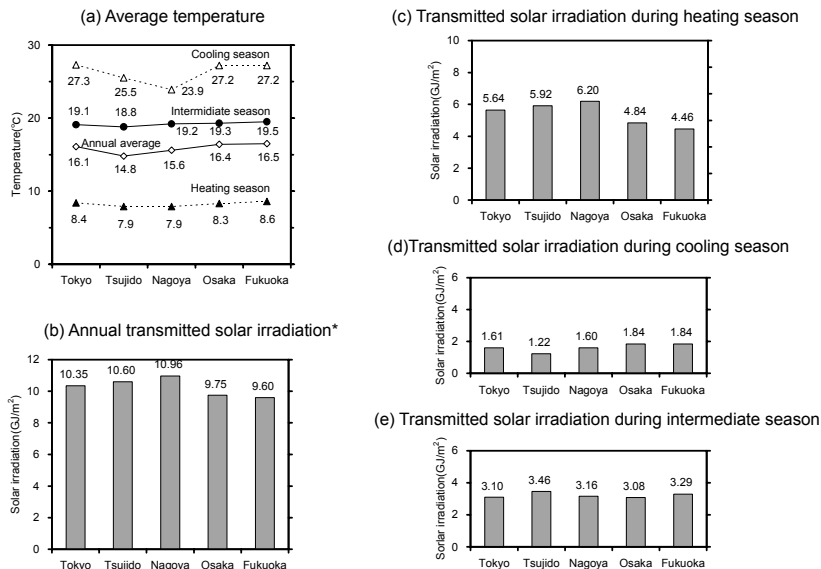


Figure 1. Comparison of temperature and transmitted solar irradiation of five cities

* in case of 3 mm single glass without solar shading equivalent to building performance vi in the standard scale model

RESULTS OF SENSITIVITY ANALYSIS

Comparison of cooling load during intermediate season in Tokyo between L₁₈ and L₂₇

As a result of sensitivity analysis, 'solar shading' and 'outdoor airflow rate' were significant at $p < 0.01$ in both L₁₈ and L₂₇. In addition, 'insulation and airtightness performance' and 'setting temperature level' were significant at $p < 0.01$, and interactions between 'outdoor airflow rate' and 'solar shading' were significant at $p < 0.05$ in L₂₇. In terms of degree of the effect on ICL, 'solar shading' was observed to be the most important factor. From this findings, it was confirmed that the space cooling with outdoor air have an effect on ICL supposing 'solar shading'. 'Solar shading' has an effect on ICL by the interaction with outdoor airflow rate as well. 'Insulation and airtightness performance' has more effect on ICL by the interaction with outdoor airflow rate than only itself. As for the two interactions in Table 5, the difference of the effect on ICL between 'outdoor airflow rate' level 'M' and 'H' was found to be small. Therefore, 'outdoor airflow rate' level 'M' is said to be more efficient than level 'H' in this case. As observed above, it seemed to be able to take the general tendency with L₁₈, and it was confirmed that the application of L₁₈ to the sensitivity analysis is valid for ICL of Tokyo.

Table 5 Comparison about results from sensitivity analysis of the average and the effect on cooling load during intermediate season in Tokyo between L₁₈ and L₂₇(*: $p < 0.05$, **: $p < 0.01$)

Factor		Level		L ₁₈ [GJ/season]	L ₂₇ [GJ/season]	
				9.526	9.822	
P	Insulation and airtightness performance	i	R2000 & 1.0cm ² /m ²	-0.03	0.00	**
		iii	1999 standard level & 2.0cm ² /m ²	-0.10	-0.24	
		vi	1992 standard level & 5.0cm ² /m ²	0.13	0.24	
S	Solar shading	E	Lace curtain & solar shading	-1.26	-1.33	**
		C	Lace curtain only	-0.72	-0.47	
		X	Nothing	1.98	1.79	
T	Setting temperature level	S	Energy saving	0.48	0.33	**
		N	Normal	-0.40	-0.15	
		R	Rich	-0.08	-0.18	
O	Outdoor airflow rate	L	Low(0 ach)	0.87	0.94	**
		M	Middle(2 ach)	-0.25	-0.32	
		H	High(8 ach)	-0.63	-0.62	
O × S	Interactions between 'outdoor airflow rate' and 'solar shading'	L × E	Low × (Lace curtain & solar shading)		-0.66	*
		L × C	Low × Lace curtain only		0.44	
		L × X	Low × Nothing		3.03	
		M × E	Middle × (Lace curtain & solar shading)		-1.64	
		M × C	Middle × Lace curtain only		-0.87	
		M × X	Middle × Nothing		1.54	
		H × E	High × (Lace curtain & solar shading)		-1.69	
		H × C	High × Lace curtain only		-0.97	
O × P	Interactions between 'outdoor airflow rate' and 'insulation and airtightness performance'	H × X	High × Nothing		0.81	*
		L × i	Low × (R2000 & 1.0cm ² /m ²)		1.23	
		L × iii	Low × (1999 standard level & 2.0cm ² /m ²)		0.69	
		L × vi	Low × (1992 standard level & 5.0cm ² /m ²)		0.88	
		M × i	Middle × (R2000 & 1.0cm ² /m ²)		-0.61	
		M × iii	Middle × (1999 standard level & 2.0cm ² /m ²)		-0.56	
		M × vi	Middle × (1992 standard level & 5.0cm ² /m ²)		0.22	
		H × i	High × (R2000 & 1.0cm ² /m ²)		-0.63	
		H × iii	High × (1999 standard level & 2.0cm ² /m ²)		-0.85	
		H × vi	High × (1992 standard level & 5.0cm ² /m ²)		-0.37	

Examination of the validity of L_{18} for annual heating load and annual cooling load in Tokyo

Table 6 presents the comparison about the results from sensitivity analysis on AHL and ACL of Tokyo with L_{18} . It was observed 'outdoor airflow rate' have an effect on only ACL. 'Insulation and airtightness performance' had a great effect on AHL, and the factor which have a great effect next to that was 'setting temperature level'. Higher insulation and airtightness performance level, lower solar shading level, and more energy saving temperature level tend to reduce AHL. The effect of each factor on ACL was found to be smaller than AHL. The tendency from Table 6 coincides with general knowledge.

Table 6 Comparison about results from sensitivity analysis with L_{18} of the average and the effect on annual heating load(AHL) and annual cooling load(ACL) in Tokyo (*:p<0.05, **:p<0.01)

Factor		Level		AHL[GJ/a]			ACL[GJ/a]
				21.204			20.752
P	Insulation and airtightness performance	i	R2000 & 1.0cm ² /m ²	-13.63			-2.00
		iii	1999 standard level & 2.0cm ² /m ²	-1.51	**		-0.43
		vi	1992 standard level & 5.0cm ² /m ²	15.14			2.42
S	Solar shading	E	Lace curtain & solar shading	4.62			-1.81
		C	Lace curtain only	-0.99	**		-1.17
		X	Nothing	-3.63			2.98
T	Setting temperature level	S	Energy saving	-7.63			-1.51
		N	Normal	-1.34	**		-0.36
		R	Rich	8.97			1.87
O	Outdoor airflow rate	L	Low(0 ach)	1.24			1.08
		M	Middle(2 ach)	-1.25			-0.26
		H	High(8 ach)	0.01			-0.82

Sensitivity analysis with L_{18} for annual heating load, annual cooling load and cooling load during intermediate season in five cities

Table 7 shows the comparison about the results from sensitivity analysis on AHL with L_{18} for five cities. As a result, three factors except for 'outdoor airflow rate' were found to be significant at p<0.01 in all five cities. As mentioned above, the factors which have an effect on AHL were found to be 'insulation and airtightness performance(±15GJ/a)', 'setting temperature level(±9GJ/a)', 'solar shading(±4GJ/a)' as the order of effect level. The effect of each factor on AHL was said to be common in five cities.

Table 8 shows the comparison about the results from sensitivity analysis on ACL with L_{18} for five cities. As a result, all four factors were found to be significant at p<0.01 in four cities except for 'insulation and

Table 7 Comparison about results from sensitivity analysis with L_{18} of the average and the effect on annual heating load(AHL) for five cities (*:p<0.05, **:p<0.01)

Factor	Level	AHL[GJ/a]	Tokyo	Tsujido	Nagoya	Osaka	Fukuoka
			21.204	23.898	26.124	22.850	22.220
Insulation and airtightness performance (P)	i	R2000 & 1.0cm ² /m ²	-13.63	-15.15	-16.46	-14.35	-13.95
	iii	1999 standard & 2.0cm ² /m ²	-1.51	-1.36	-1.70	-1.26	-1.29
	vi	1992 standard & 5.0cm ² /m ²	15.14	16.52	18.16	15.61	15.24
Solar shading (S)	E	Lace curtain & solar shading	4.62	4.42	4.85	4.15	3.92
	C	Lace curtain only	-0.99	-0.53	-0.49	-0.50	-0.59
	X	Nothing	-3.63	-3.89	-4.36	-3.65	-3.34
Setting temperature level (T)	S	Energy saving	-7.63	-8.20	-8.57	-7.94	-7.98
	N	Normal	-1.34	-0.43	-0.39	-0.39	-0.34
	R	Rich	8.97	8.63	8.95	8.34	8.31
Outdoor airflow rate (O)	L	Low(0 ach)	1.24	1.28	1.38	1.24	1.22
	M	Middle(2 ach)	-1.25	-1.06	-1.19	-1.02	-0.95
	H	High(8 ach)	0.01	-0.22	-0.19	-0.21	-0.27

airtightness performance' of Tsujido. 'Insulation and airtightness performance' of Tsujido was found to be significant at $p < 0.1$. ACL and transmitted solar irradiation during cooling season of Tsujido were lower than other four cities as shown in Table 8 and Figure 1(d). Tsujido which climate is oceanic can be said to be a particular location compared to other four cities. The effect levels on ACL which the factors have were found to be within $\pm 3\text{GJ/a}$. 'Solar shading' was found to be the factor which have a large effect on ACL in common with all five cities, but there was small difference in the effect level on ACL compared to that on AHL.

Table 9 shows the comparison about the results from sensitivity analysis on ICL with L_{18} for five cities. The result of ICL varied in each city and it was different from that of AHL and ACL. This is probably because the climate condition during intermediate season of each city is different, although five cities belong to Zone IV. 'Solar shading' and 'outdoor airflow rate' were found to be significant at $p < 0.1$ in common with five cities, and the former ($\pm 2\text{GJ/season}$) have a larger effect than the latter ($\pm 1\text{GJ/season}$). These two factors can be said the important factors which have an effect on ICL.

Table 8 Comparison about results from sensitivity analysis with L_{18} of the average and the effect on annual cooling load(ACL) in five cities (Δ : $p < 0.1$, *: $p < 0.05$, **: $p < 0.01$)

Factor	ACL[GJ/a]		Tokyo	Tsujido	Nagoya	Osaka	Fukuoka
	Level		20.752	15.279	23.223	22.981	24.425
Insulation and airtightness performance (P)	i	R2000 & 1.0cm ² /m ²	-2.00	-0.09	-2.42	-2.65	-2.22
	iii	1999 standard & 2.0cm ² /m ²	-0.43	-0.32	-0.27	-0.55	-0.26
	vi	1992 standard & 5.0cm ² /m ²	2.42	0.41	2.69	3.21	2.49
Solar shading (S)	E	Lace curtain & solar shading	-1.81	-2.14	-2.07	-2.08	-2.34
	C	Lace curtain only	-1.17	-0.82	-0.97	-1.01	-0.96
	X	Nothing	2.98	2.95	3.03	3.09	3.30
Setting temperature level (T)	S	Energy saving	-1.51	-1.02	-1.37	-1.85	-1.65
	N	Normal	-0.36	-0.04	0.00	-0.04	0.00
	R	Rich	1.87	1.06	1.37	1.90	1.65
Outdoor airflow rate (O)	L	Low(0 ach)	1.08	1.10	1.20	1.16	1.31
	M	Middle(2 ach)	-0.26	-0.28	-0.23	-0.14	-0.09
	H	High(8 ach)	-0.82	-0.82	-0.97	-1.02	-1.22

Table 9 Comparison about results from sensitivity analysis with L_{18} of the average and the effect on cooling load during intermediate season(ICL) in five cities (Δ : $p < 0.1$, *: $p < 0.05$, **: $p < 0.01$)

Factor	ICL[GJ/season]		Tokyo	Tsujido	Nagoya	Osaka	Fukuoka
	Level		9.526	9.200	12.012	10.149	11.356
Insulation and airtightness performance (P)	i	R2000 & 1.0cm ² /m ²	-0.03	0.47	-0.44	-0.39	-0.04
	iii	1999 standard & 2.0cm ² /m ²	-0.10	-0.16	0.00	-0.16	0.01
	vi	1992 standard & 5.0cm ² /m ²	0.13	-0.31	0.43	0.55	0.03
Solar shading (S)	E	Lace curtain & solar shading	-1.26	-1.55	-1.58	-1.53	-1.74
	C	Lace curtain only	-0.72	-0.56	-0.49	-0.46	-0.43
	X	Nothing	1.98	2.11	2.07	1.99	2.17
Setting temperature level (T)	S	Energy saving	0.48	0.32	0.50	0.35	0.40
	N	Normal	-0.40	0.02	-0.02	0.01	-0.04
	R	Rich	-0.08	-0.34	-0.48	-0.36	-0.36
Outdoor airflow rate (O)	L	Low(0 ach)	0.87	0.98	0.96	0.94	1.03
	M	Middle(2 ach)	-0.25	-0.28	-0.19	-0.11	-0.05
	H	High(8 ach)	-0.63	-0.70	-0.77	-0.83	-0.98

INFLUENCE OF DIFFERENT CLIMATIC CONDITIONS ON ANNUAL HEATING & COOLING LOAD

Figure 2 shows the comparison of relation between outdoor airflow rate and AHL or ACL of five cities with heating degree day(HDD) and cooling degree day(CDD) as the index of climate conditions under the solar shading condition of 'lace curtain & solar shading(E)'. From Figure 2(a), 'outdoor airflow rate' seems not to have any effect on AHL except for Tokyo in this three case(0 ach, 2 ach, 8 ach). As shown in Figure 2(a), standardized AHL in case of 'low airflow rate' of Tokyo as 100 and HDD 14-10 of Tokyo as 100, relative AHL values in Osaka and Fukuoka were found to be larger considering their HDD. Solar irradiation would be not completely shaded in this case(E), so this is likely due to the smaller transmitted solar irradiation during heating season in these two cities. Next, from Figure 2(b), 'outdoor airflow rate' seems to have small effect on ACL except for Tokyo in this three case(0 ach, 2 ach, 8 ach) as well as AHL in Figure 2(a). As seen in Figure 2(b), standardized ACL in case of 'low airflow rate' of Tokyo as 100 and CDD 24-24 of Tokyo as 100, relative ACL values in Tsujido, Nagoya and Fukuoka were found to be larger considering their CDD. It was probably because transmitted solar irradiations during intermediate season of the three cities are larger than other two cities. In summary, the difference of tendency on AHL and ACL in each city could be explained by the difference of climate conditions such as transmitted solar irradiation.

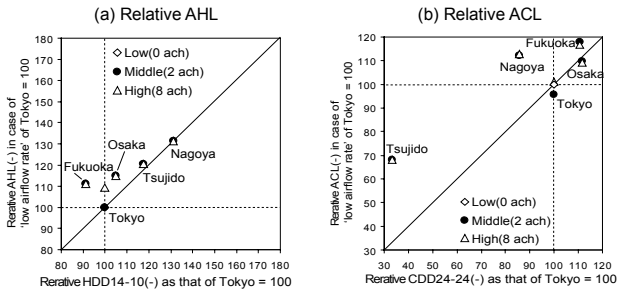


Figure 2. Comparison of relation between outdoor airflow rate and relative AHL or ACL of five cities under the solar shading condition of 'lace curtain & solar shading'.

CONCLUSIONS

Following conclusions are drawn from this study:

- 1) Three parameters (insulation and airtightness performance, solar shading, setting temperature level) except for outdoor airflow rate are significant in AHL in all five cities.
- 2) All four parameters are significant in ACL in all five cities.
- 3) Solar shading and outdoor airflow rate are significant factors in ICL in common with all five cities, but some cities show a different tendency in significant ones which is caused by the difference of climate conditions during intermediate season.
- 4) Solar shading level has an effect on ICL by the interaction with outdoor airflow rate.
- 5) There is a difference in tendency of AHL and ACL in five cities even though they belong to the same climate zone IV in the Japanese residential standard, and it could be explained by the difference of climate conditions such as transmitted solar irradiation and average temperature in each season.

In conclusion, climate condition in each city would be considered in the application of space cooling with outdoor air, even though investigated cities are categorized into the same climate zone in Japan.

REFERENCES

1. H. Akasaka et al. (2003) "Expanded AMeDAS Weather Data", published by Maruzen.