THE ENERGY CONSUMPTION OF THE PUBLIC BUILDINGS IN OSAKA, JAPAN

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ABSTRACT

The aim of this research work is to investigate the actual energy consumption in existing public buildings and to obtain the basic data for energy conservation of these buildings. Various monthly energy consumption data of public buildings in Osaka for the period from April 2000 to March 2002 was gathered and analyzed to determine the nature of the energy consumption of buildings. One of the investigated buildings is selected as the typical building and the heat load is calculated. The calculated values of the energy consumption are compared with the investigation values.

KEYWORDS

Energy consumption, Public building, Simulation

INTRODUCTION

As we all know, nowadays natural resources are becoming scarce, so energy conservation is becoming a more and more important problem all over the world. In Japan, energy conservation has been a tradition for a long time, Researchers have been endeavoring in different sectors, to identify methods of energy conservation. In pursuit of this goal, research on energy consumption of buildings was actively conducted in Japan recently. However, much of the previous research was targeted at residences and office buildings. There is little research about public buildings. In this paper, we investigated the actual energy consumption in existing public buildings in Osaka, Japan, and analyzed basic data for the energy conservation of these buildings.

Table1 Investigation locations

Object	Amount
Ward office	20
Civic hall	25
Fire station	21
Child care center	26
Indoor swimming pool	9
Environmental business center	4
Total	105

Table 2 List of collection data item

Item	Unit
Floor space	m²
Structure	S /SRC /RC
Numbers of floors	floor
Completion year	year
Use	office etc.
Location	address
Monthly electric consumption	kWh/ month
Monthly gas consumption	m³/ month
Monthly water consumption	m³/month
Hours of use	h
Total floor space	m²

ENERGY CONSUMPTION

1 Types of energy consumption in buildings

This paper focuses on six kinds of public buildings of local governments in Osaka City. In total, 105 cases of energy consumption data were gathered. The investigated locations and data items are shown in Table 1 and Table 2, respectively.

With a conversion factor in Table 3, the electric consumption and gas consumption are converted into primary energy. The calculated items of each building are :

1) Monthly and yearly electric consumption
2) Monthly and yearly gas consumption
3) Monthly and yearly water consumption
4) Monthly and yearly energy consumption

Table 3 Conversion factor to primary energy

	Unit heat capacity	
Electric	10.25	MJ/kWh
Gas	45.9	MJ/m³

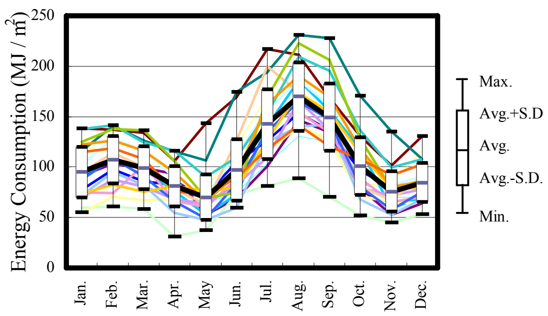

Fig. 1 Monthly average energy consumption in ward offices (average value of three years)

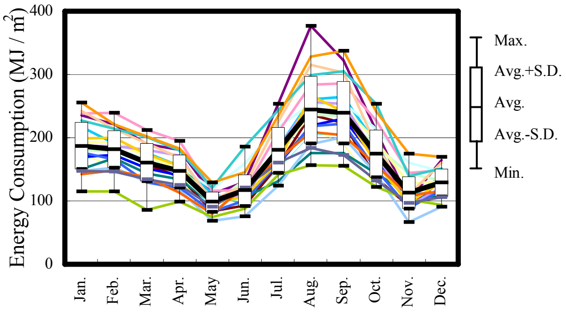

Fig. 2 Monthly average energy consumption in fire stations (average value of three years)

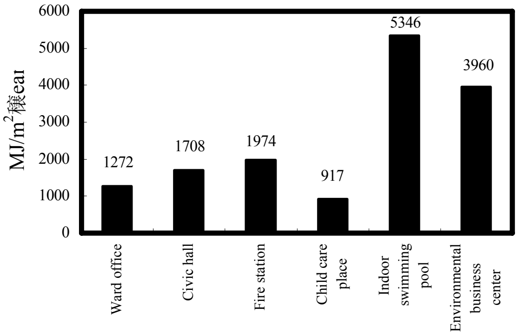

Fig. 3 Yearly average energy consumption in public buildings (average value of three years)

Table 4 Conversion factor to CO_2 discharge

	Discharge coefficient of CO_2	
Electric	0.357	kg CO_2/kWh
Gas	2.15	kg CO_2/m^3

Figures 1-3 indicates the monthly and yearly energy consumption of each building. For each type of energy consumption, the peak loads are found in summer and winter with maximum standard deviations.

2 CO_2 discharge evaluations

With the conversion factor shown in Table 4, the values of CO_2 discharge are shown in Fig. 4. The CO_2 discharge has small value of 40~80kg/m^2 yearly in ward offices, civic hall, fire stations and child care centers, whereas it has big values of 160-210kg/m^2 in indoor swimming pools and environmental business centers.

3 Relationship between energy consumption and outdoor air temperature

Figure 5 shows the relation between the average monthly energy consumption and the average monthly outdoor air temperature. The correlation coefficients are –0.7 and 0.83 respectively, and the correlations with the energy consumption and the outdoor air temperature have been reaffirmed through other research.

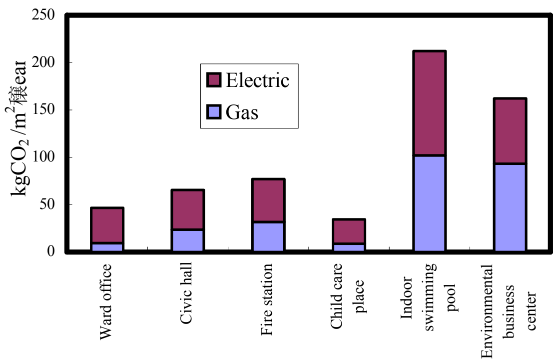

Fig. 4 CO_2 discharge

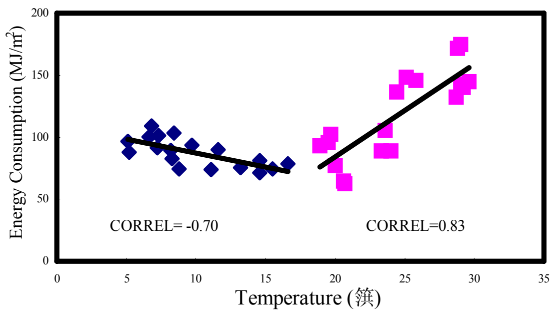

Fig. 5 Correlation between energy consumption and outdoor air temperature

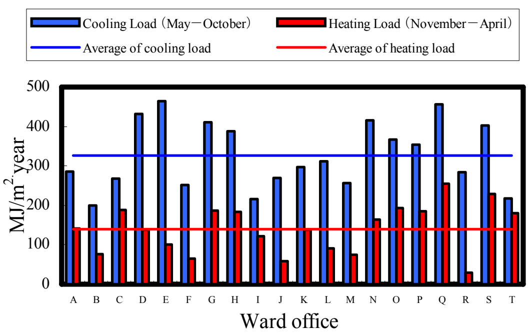

Fig. 6 Estimated yearly cooling and heating load in ward office buildings

4 Estimation of cooling load and heating load

Looking at Fig.1 and Fig.2, two peaks in the annual fluctuation of energy consumption of each building are evident. In a building, energy is usually used for lighting, elevators, hot water supply, office equipment, ventilation, heating/cooling etc. Here, the energy that is used for lighting, elevators, hot water supply, office equipment and ventilation is assumed to have the same value at each month of the whole year. Fluctuation of the energy consumption is assumed to be caused by heating and cooling. In the months for which the primary energy consumption is the minimum of the whole year, the heat load is considered to be zero. Since the primary energy consumption of some months is assumed to be the base load of the whole year, the excess load over the base load in other months is assumed to be the heat load. By using this technique, the cooling load and heating load are estimated for the whole year. Figure 6 shows the yearly load for cooling load and heating load in ward office buildings. Cooling loads are bigger than heating loads in all buildings.

5 Comparison with previous research work

Comparison of the results in ward office buildings and fire station buildings with the previous research work is as follows:

(1) Comparison of primary energy consumptions

Table 5 is the comparison of the primary energy consumption in office buildings. For ward office buildings, the yearly primary energy consumption is 1272MJ/m^2·year, which is smaller than that in any of the previous research work. This might be explained by possible use of energy-saving control systems which control the usage time of the air conditioning and lighting in ward office buildings. In fire station buildings, the yearly primary energy consumption is 1974 MJ/m^2·year, which matches the normal value in the previous research works.

(2) Comparison of cooling load and heating load

According to Fig. 7, the cooling load and heating load in ward office building account for 40% of the total energy consumption. In fire station buildings, the energy consumption for the heating load and cooling load is bigger than that in other research works.

(3) Relationship between primary energy consumption and year of construction

The nature of energy consumption in buildings has changed since the Energy Conservation Law was enacted in 1980. Buildings which were completed after 1980, tend to have less energy consumption than those which were completed before 1980, as seen in Fig.8. As for the fire station buildings discussed in this paper, the same tendency is recognized.

Table 5 Comparison of primary energy consumption with previous research work

	Use	Location	Energy consumption (MJ/m^2·year)	Period of investigation	Reference
This study	Ward office	Osaka	1272	2000－2002	
	Fire station	Osaka	1974	2000－2002	
Previous works	Office buildings	Kinki	2634	1997－1999	(Hayakawa S. and Hiromi K. 2004)
	Office buildings	Kansai	1732	1993	(Maekawa T. et al. 1995)
	Office buildings	Hiroshima	1573	1994	(Takeda N. et al. 1995)
	Government office buildings	(Japan)	1510	1997－2004	(The Energy Conservation Center, Japan.2005)
	Normal office buildings	(Japan)	2225	1997－2005	(The Energy Conservation Center, Japan .2006)

(4) Relationship between primary energy consumption and total floor area

According to previous research, energy consumption tends to increase as the building scale becomes bigger. In ward office buildings, the cooling consumption and heating consumption tend to increase with the increase of a building scale, as shown in Fig. 9.
In other buildings, we did not see this tendency. This is probably because the total floor space distribution is unequal and the data is insufficient.

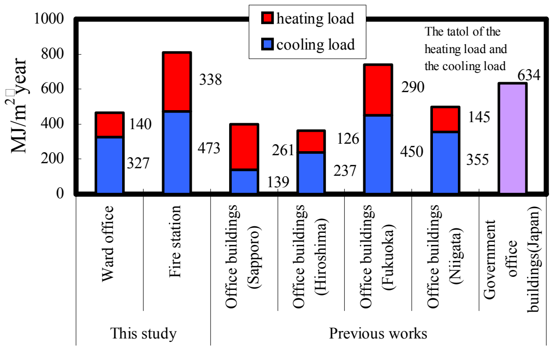

Fig. 7 Comparison of cooling load and heating load with previous research works

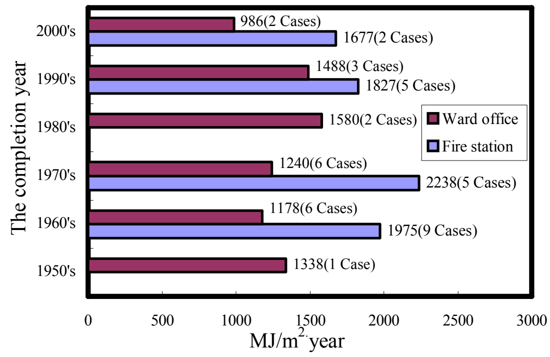

Fig. 8 Primary energy consumptions by classifying buildings according to the year of construction

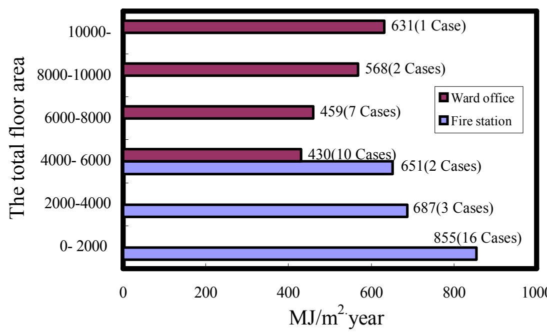

Fig. 9 Primary energy consumptions by classifying buildings according to the total floor area

SIMULATION OF HEAT LOAD

6.1 Simulation

One of the investigated buildings is selected as a typical building. In Fig. 10, the 3rd floor as a standard floor is shown. The heat load is calculated through a simulation program called NEW HASP/ACLD-β. By using this program, the possibility of energy conservation by changing building specifications is examined. The calculation conditions are shown in Table 6 and Table 7. Expanded AMeDAS Weather Data of 2000 in Osaka is used.

Table 6 Indoor load

Occupancy	Lighting load	Equipment load	Ventilation
0.2person/m²	25W/m²	5.8W/m²	7.2m³/m²h

Table 7 Calculation conditions of indoor

	Indoor temperature (ºC)	Indoor humidity (%)
Dec.-Mar.	22	40
Jun.-Sep.	26	60
Apr., May, Oct. and Nov.	22-26	40-60

6.2 Calculation results

Calculated heating load and cooling load of each floor is shown in Table 8. The heat loads, which were provided by a calculation and the real consumption for each month in the whole year, are shown in Fig. 11. The shape of the curves of the simulation result and the real consumption are about the same form.

Annual calculated heat load of the building is 433MJ/m^{2}·year. Comparing with the annual air-conditioning energy consumption of the simulated ward office, which was estimated to be 558MJ/m^{2}·year, the heat load by calculation is smaller than real consumption. The reason is that we assumed a general situation as the model condition.. The values used by simulation should be somewhat different from the practical application. Therefore, differences occur between air-conditioning load based on simulation and investigation.

6.3 Examination about energy conservation

By changing the architectural specifications, such as repairing of drafts and air leaks, change of insulation materials, and so on, the possibility of energy conservation is examined based on the simulations. Figure. 12 shows the heat load of the building when 6mm-thick common glass was changed to infrared-ray absorbing 6mm-thick glass, double-paned glass (using two panes of common glass), and double-paned glass (using one pane of infrared-ray absorbing glass and one pane of common glass) for classification. We could see that the heat load falls 4% when the double-paned glass was used in the windows. This figure also shows the results for different thicknesses (25mm, 50mm, 75mm and 100mm) of styrene foaming board as the outer wall insulation. The heat load falls about 4% when the thickness of the insulation material was changed to 50mm. However, the energy conservation effect can not be expected to significantly increase for thicknesses over 50mm.

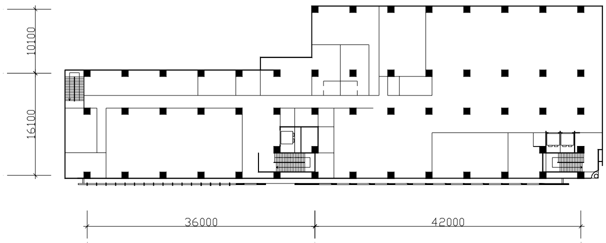

Fig. 10 Standard plan (third floor)

Table 8 Annual heat loads in each floor

	Annual load for heating (MJ/m^{2}·year)	Annual load for cooling (MJ/m^{2}·year)	Total load (MJ/m^{2}·year)
1st floor	89	346	435
2nd floor	90	347	437
3rd floor	108	323	431
4th floor	101	334	435
5th floor	140	281	421
Average	101	331	433

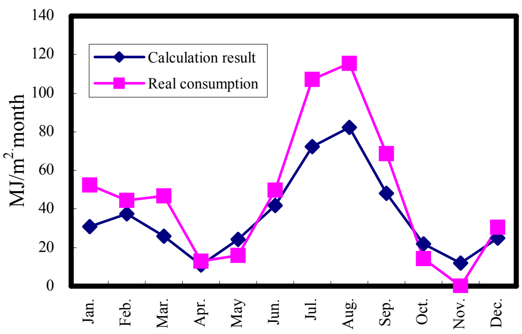

Fig. 11 Calculated heat load and real consumption

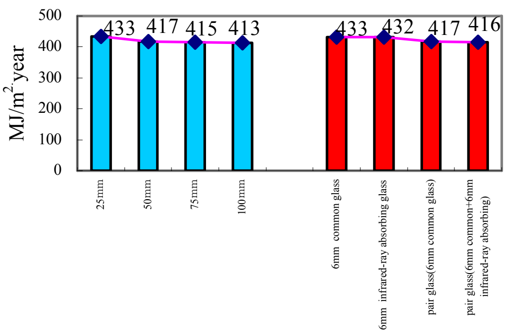

Fig. 12 Energy conservation effect by changing the architectural specifications

CONCLUSION

The results of this investigation of energy consumption in public buildings are shown as follows:

1) Electric power, gas, water and the primary energy consumption of each building were shown. They can be assumed as the basic data for the energy conservation diagnosis.
2) The peaks of energy consumption of buildings appeared in summer and winter.
3) It is reconfirmed that the energy consumption has strong correlation with outdoor air temperature.
4) Energy conservation effects can be realized by improving the thermal characteristics of the windows and changing the thickness of the insulation of the outer walls.

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