A Study on the Environmental Load of Office Buildings in Seoul

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Key words : Office buildings, Environmental load, Energy consumption, CO_2 emission quantity

Abstract

This study is to examine the emission quantity of CO_2 gas as the environmental load in office buildings. After the investigation of monthly consumption of each energy source (electricity and natural gas), it is analyzed that the CO_2 emission quantity of 34 office buildings surveyed is 22.4 kg-c/㎡·year, which consists of 17.5 kg-c/㎡·year by consuming electricity, and 4.9 kg-c/㎡·year by consuming natural gas. And the CO_2 emission quantity of each load in those buildings consists of 68% emitted by general electricity, 16% by cooling load and 16% by heating load. It is also proposed that the CO_2 emission quantity of cooling and heating load is profoundly pertinent to the variation of outdoor temperature.

Nomenclature

C_{cm} : Monthly CO_2 emission rate by cooling load [kg-c/㎡·month]
C_{hm} : Monthly CO_2 emission rate by heating load [kg-c/㎡·month]
T_m : Monthly average outdoor temperature [℃]

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1. Introduction

To prevent global warming, the Kyoto Protocol to the United Nations Framework Convention on Climate Change was adopted in December 1997, which indicated that developed countries should reduce the greenhouse gas emission to 1990 levels between 2008 and 2012 by average 5.2%. Although we are excluded from the obligation to reduce the greenhouse gas emission at this time, we ought to participate in the Convention in the near future. Still more, the CO_2 emission quantity of

Korea ranked high as 11th grade in the world, and the CO_2 emission quantity increased in 10~15% while the average raise of the world showed only between 0.5% and 1.4% year by year.

It is suggested that we should concern ourselves about energy-saving methods such as development of alternative energy, efficient use of energy, and so forth.

Regarding the energy consumption as the environmental load, this study is to present the fundamental data for establishing environmental load criteria by assessing the emission quantity of CO_2 emitted by the energy consumption for operating office buildings.

2. General Concept of Environmental Load and Recent State of Developed Countries

2.1 General Concept of Environmental Load

Carbon dioxide (CO_2) considered as the major cause of global warming is generated chiefly by the combustion of fossil fuels. Especially, buildings that consist of various materials are spending lots of energy throughout the whole life cycle from the production of materials, construction, maintenance and finally to the disposal stage. Considering the case of Japan, it's investigated that the energy consumption through these process consists of 1/3 of the total national energy consumption[1].

In brief, lots of resources and energy are consumed when buildings are constructed, operated and disposed including the production of materials. The studies on LC CO_2 (Life Cycle CO_2), BEES, etc. assessing these quantity are surveyed vigorously from the aspect of global warming prevention in Japan, USA. With this kind of method, the emission quantity of CO_2, emitted by the use of resources and energy at each stage of construction (including the production of materials), operation, maintenance and renovation, can be estimated. And the quantity of CO_2 emission per year is calculated by dividing the total by the lifetime of the building. These are used as the indicators assessing the environmental load over the world caused by the construction activities. The environmental load represents the quantity of CO_2 emission by the energy consumption. Each CO_2 emission criterion is used by energy source because the quantity of CO_2 emission varies with the source.

According to the calculated result of CO_2 emission of the buildings' lifetime, the CO_2 emission of the building by the energy consumption for heating, cooling and lighting consists of over 50%[2].

2.2 Recent State of Developed Countries

In developed countries, BREEAM(Building Research Establishment Environmental Assessment Method) proposed by BRE in Britain is presented and applied to offices, houses, stores, industrial facilities, and so on for leading to the environmental design throughout the assessment of global, local and interior environment and resource use. And, the classified assessment presents the standard amount and guidelines for each part. BREEAM classifies the level with the environmental load by the energy consumption and recognizes the level of the environment-friendly building. For example, it is divided into 10 levels from 120 kg/㎡·year to 35 kg/㎡·year for new office buildings and the level of existing office build-

ings is also set up[3].

In Britain, 25% of the new office buildings are assessed by BREEAM. The sufficient number of buildings assessed attributes to the useful utilization by architects and owners. That is, it gives architects the clear purpose, and also provides owners the letter of guarantee issued by BREEAM in Britain. And tenants can use this letter of guarantee as the material for publicizing benefits of the building at the time of the building transfer. In Canada, the method is accomplished leading to the advanced control of the environmental load by the energy consumption at the stage of design and the efficient energy use by BEPAC (Building Environmental Performance Assessment Criteria)[4].

3. Investigation of Energy Consumption

3.1 Range and Method of Investigation

To survey the quantity of energy consumption for analyzing the environmental load of office buildings, the monthly quantity of energy consumption by source of the buildings in Seoul for five years(1992-1996) was investigated. The 34 office buildings were selected for investigation among the buildings - buildings which should report the quantity of energy consumption to KEMCO(Korea Energy Management Corporation) based on Article 20, Clause 1 of the Energy Use Rationalization Law on the basis of 1994 level-which consumed either heat or electricity over 500 TOE per year.[5] And the consumption quantity of electricity and natural gas, the present state of construction and equipment over those buildings were grasped. The investigation method is as follows. After preparing, distributing and making them fill out the questionnaire, investigators visited those buildings and talked with managers in charge to amass the related materials including the missing data.

3.2 Recent State of Energy Consumption

The energy source used at office buildings in Seoul had been diesel oil, bunker C oil, natural gas, electricity, and so on until 1988, when the use of clean energy is obligatory on buildings of which boiler capacity is over 2 ton(the use of clean energy became obligatory on buildings of which average exclusive area is over 30 pyong and boiler capacity is over 0.5 ton in 1991), but is only natural gas and electricity now.

The energy consumption of the 34 office buildings from 1992 to 1996 is presented by each 175, 184, 195, 205, and 212 Mcal/m²·year. Considering them by energy source, electricity consists of about 63%(122 Mcal/m²·year) and natural gas about 37%(72 Mcal/m²·year).

4. Analysis of Environmental Load

4.1 Summary

(1) Range of environmental load analysis

A building consumes lots of resources and energy from construction to dismantlement. That is, it consumes lots of energy at the time of operation including material production, transportation to the construction field, construction process, cooling, heating, hot water, lighting, maintenance, and so on. And it eventually acts as the environmental load. This study is limited to the environmental load based on the energy consumption of office buildings even though the lifetime of buildings should be considered to draw the en-

Table 1 CO_2 emission factors of energy sources

Energy source	CO_2 emission factor
gasoline	0.079146 kg-c/Mcal
kerosene	0.081658 kg-c/Mcal
gas oil	0.084590 kg-c/Mcal
LPG	0.072027 kg-c/Mcal
LNG	0.068 kg-c/Mcal
heavy oil	0.088358 kg-c/Mcal

Source : OECD, National inventories of net green house gas emission, 1992. pp. 2~8.

vironmental load from buildings.

(2) Calculation of environmental load

The environmental load of office buildings were analyzed based on the monthly energy consumption of the 34 office buildings for five years(1992-1996).

The environmental load(CO_2 emission) by energy consumption from the point of operating process is calculated on the basis of the monthly consumption of natural gas and electricity used for cooling, heating, hot water, and lighting, and the operation of various equipment. The unit kg-c(c means carbon) is used for representing the quantity of CO_2 emission.

In this study, the CO_2 emission criterion of natural gas used for drawing the environmental load is the unit of natural gas represented by OECD as the following Table 1.[6] As for electricity, it is used 0.124kg-c/kWh represented by KEPC(Korea Electric Power Corporation), the CO_2 emission criterion when producing 1kWh electricity.

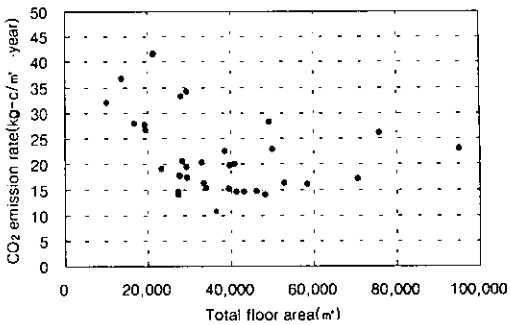

Fig. 1 Annual CO_2 emission from each office buildings investigated(5-years average).

4.2 Analysis of Environmental Load by Factors

(1) CO_2 emission by the total area

The following Figure 1 shows the average CO_2 emission per year based on the total area targeting the quantity of energy consumption for five years(1992-1996). As the total area got increasing, the quantity of CO_2 emission tended to gradually decrease and then increase again. The quantity of emission, however, showed the prominent differences even in buildings of the same scale. The buildings investigated are classified into less than 20,000 m²(5 buildings), more than 20,000 m² less than 30,000 m²(11 buildings), more than 30,000 m² less than 40,000 m²(6 buildings), and more than 40,000 m² less than 50,000m²(7 buildings) and more than 50,000 m²(5 buildings) based on the total area. Each yearly quantity of CO_2 emission is 30.2, 24.9, 18.3, 18.5 and 19.8 kg-c/m²·year as the following Figure 2.

(2) CO_2 emission by energy source

The result analyzed from the quantity of CO_2 emission in proportion to each consumption of electricity and natural gas, the energy sources of office buildings, is as fol-

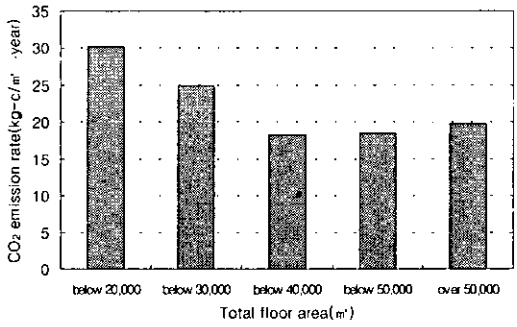

Fig. 2 CO_2 emission rate classified by total floor area of buildings.

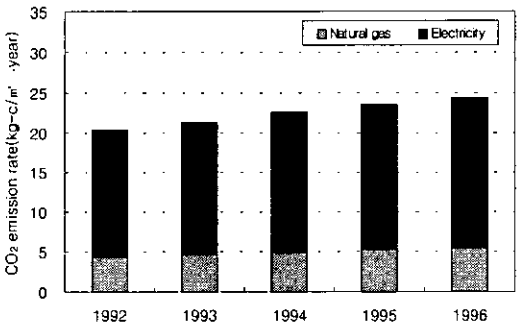

Fig. 3 CO_2 emission rate of each energy sources.

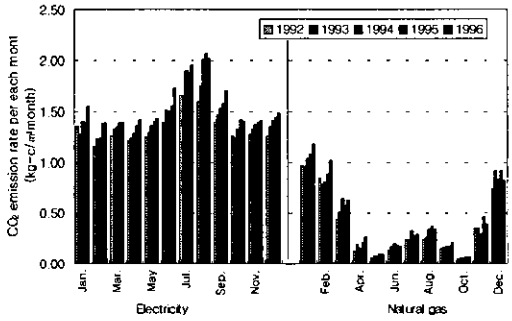

Fig. 4 Monthly CO_2 emission of each energy sources for 5 years.

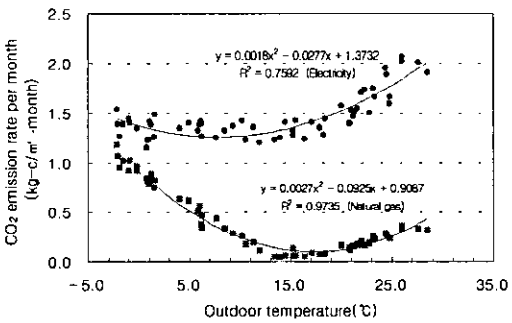

Fig. 5 Monthly CO_2 emission according to outdoor temperature.

lows. First, the quantities of CO_2 emission based on the electricity consumption were 16.1, 16.7, 17.7, 23.6, 24.4 kg-c/m²·year from 1992 to 1996, and the quantities based on the natural gas consumption were 4.3, 4.7, 4.9, 5.3, 5.5 kg-c/m²·year. The quantity of emission showed about less than 4% increase an year by energy source as seen in Figure 3. Figure 4 shows the result analyzed from the quantity of monthly CO_2 emission of office buildings investigated. Figure 5 shows the quantity by energy source based on the change of monthly average outdoor temperature. As shown in Figure 5, the quantity of emission by natural gas used for air-conditioning showed close relationship with outdoor temperature, but the quantity of emission by electricity indicated relatively less relationship with outdoor temperature because electricity should be consumed for none-air-conditioning use.

(3) CO_2 emission by each load

The quantity of CO_2 emission on the basis of the investigation of energy consumption in buildings is analyzed by load. The quantity of CO_2 emission based on the consumption of general electricity makes up 68% of the total, and the quantity of CO_2 emission based on the consumption of cooling and heating make up each 16%, as shown in Figure 6.

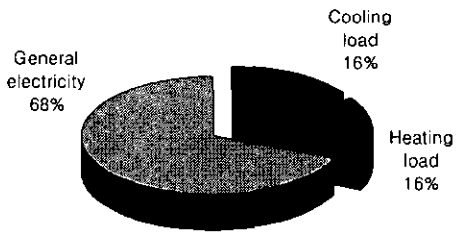

Fig. 6 Composition ratio of CO_2 emission rate.

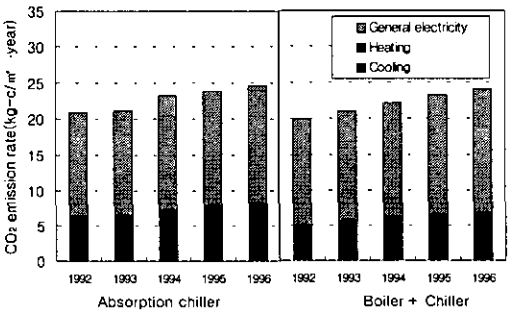

Fig. 8 CO_2 emission rate of each loads classified by equipment combination.

The result that the quantity of CO_2 emission is analyzed by load per five year average is as the following Figure 7. Figure 8 shows the yearly quantity of CO_2 emission by each load over 8 buildings operating absorption chillers and 23 buildings operating compression chillers and boilers separately among the investigated buildings. The yearly pattern of consumption was shown similarly between two building groups. The quantity of CO_2 emission based on the energy consumption of compression chillers was a little higher in the buildings operating absorption chillers.

The monthly quantity of CO_2 emission by load based on the monthly average outdoor

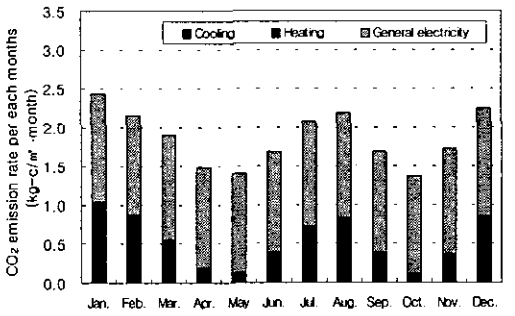

Fig. 7 Monthly CO_2 emission of each loads.

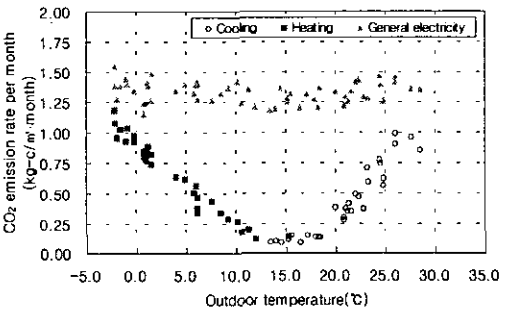

Fig. 9 CO_2 emission rate of each loads according to outdoor temperature.

temperature is as the following Figure 9. Especially the change of the CO_2 emission quantity based on the cooling and heating load is presented as the quadratic equation about the monthly average outdoor temperature such as formula (1) and formula (2). This equation shows high resolution value as the equation in Figure 10 and Figure 11, and suggests that the quantity of CO_2 emission based on the energy consumption by cooling and heating load is closely related to the change of outdoor temperature.

$$C_{cm} = 0.0033\ T_m^{\,2} - 0.0692\ T_m + 0.3904 \quad (1)$$

$$C_{hm} = 0.0019\ T_m^{\,2} - 0.0829\ T_m + 0.9077 \quad (2)$$

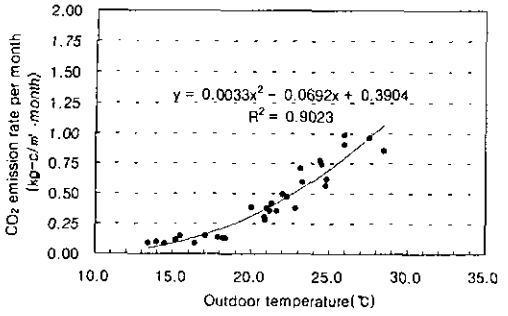

Fig. 10 CO_2 emission rate by consuming for *cooling according to outdoor temperature.*

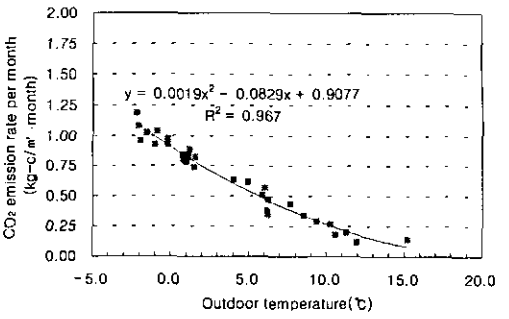

Fig. 11 CO_2 emission rate by consuming for *heating according to outdoor temperature.*

5. Conclusions

The quantity of CO_2 emission is analyzed from 1992 to 1996 on the basis of the energy consumption of the 34 office buildings in Seoul, whose energy consumption is over 500 TOE per year. The results are as follows.

(1) The average energy consumption of office buildings investigated for five years(1992-1996) is 194 Mcal/m²·year, which is made up of about 63 %(122 Mcal/m²·year) of electricity and about 37 %(72 Mcal/m²·year) of natural gas.

(2) By analyzing the quantity of CO_2 emission with energy source, it is proved that electricity is 17.5 kg-c/m²·year and natural gas is 4.9 kg-c/m²·year. The average environmental load over office buildings investigated is 22.4 kg-c/m²·year.

(3) When calculating the quantity of CO_2 emission by energy usage, the quantity of CO_2 emission by the consumption of general electricity consists of 68 % of the total, and the quantity by the energy consumption of the cooling and heating consists of each 16%.

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