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COMPARATIVE STUDY ON THE AMOUNT OF CO_2 EMISSION OF BUILDING MATERIALS BETWEEN REINFORCED CONCRETE AND STEEL STRUCTURE BUILDINGS USING THE INPUT-OUTPUT ANALYSIS

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Summary

During the life cycle of a building, it consumes energy and resources as well as emits carbon dioxide. This paper shows the amount of the energy consumption and CO_2 emission of building materials in a construction stage. The 2 types of 4 public buildings were selected for the analysis, which building's structural types are a reinforced concrete and steel skeleton structure. The Input-output analysis is applicated in this research and the results show that energy consumption unit of steel structure are 1,126Mcal/m_2 and 1,283Mcal/m_2. It is higher than the unit of reinforced concrete structure which are 848.8Mcal/ m_2 and 809.7Mcal/ m_2. These values resulted from the differences of required building materials according to the building structure. The results of CO_2 emissions shows similar tendency to the energy consumption. In the steel structure, the energy consumption and CO_2 emission of shaped steel and cold strip iron are higher than any other building materials. And the energy consumption and CO_2 emission of steel bar and ready mixed concrete are higher than any other building materials in the reinforced concrete building.

1. Introduction

1.1 Research Backgrounds and Objectives

Various researches for resource-saving and environment-friendly products have been conducted by every private and public sector in Korea. In the building industry, it has been required to develop sustainable technologies for planning skills, construction methods, building products over the building life cycle. These technologies are becoming to be focused on reduce un-renewable resources and fossil energy consumption to minimize the environmental loads from buildings when using goods during the stages of production, use and disposal. To estimate the reduction of the energy consumption and CO_2 emission of a building in detail, it is needed to calculate them before construction. In this case, the Input-output Analysis could be used to evaluate the energy consumption and CO_2 emission of building materials and products.

In this paper, the energy consumption and CO_2 emission of building materials were assessed by the Input-output Analysis focused on the construction stage of a public building. The result of this study could be used as a basic data to analyze the properties of building materials in CO_2 emission by types of buildings.

1.2 Methodology

The Input-output analysis was applied to assess the resource and energy consumption, and CO_2 emission of a public building during a construction stage. The Input-output Table explains the inter-industry linkages among various industries(cf. a building product industry to an energy industry). The methodology to estimate the amount of the energy consumption and CO_2 emission of a public building is as follows;

First, a procedure to estimate the amount was suggested in terms of input-output flows. In this paper, the amount of energy consumption means the embodied energy of building products. Second, a coefficient ratio was prepared based on the Input-output Table released by the Bank of Korea. The industry sectors were classified into 31 sectors and the rest, and the 31 sectors have a relationship with the building industry directly and indirectly. Third, the final products required by the target buildings were collected and the quantity of the products was calculated based on the estimation reports of the buildings. The estimation of the amount of the energy consumption and CO_2 emission was performed by types of construction and building materials. Fourth, the result was suggested using unit by area. The unit of energy consumption is Mcal/m^2 and CO_2 emission kg-C/ m.

1.3 Scope and Contents

The public buildings in this paper are post office buildings constructed in 1999 by the Korean Government. A total of 4 buildings were analyzed to compare the differences of the environmental load by a structural system. Two buildings were constructed with a reinforced concrete structural system and the others were by a steel skeleton system.

Table 1. Overview of target buildings

building	SS1	SS2	RC1	RC2
areas	409 m_2	359 m_2	376 m_2	423 m_2
story	2F	2F	2F	3F
structural type	reinforced concrete		steel	

Table 1 shows that the buildings have a similarity in size and areas, and it means it could show the tendency of CO_2 emission by building types. On a construction stage, CO_2 is generated during a production of material, transportation and site works. The stage includes building works, civil works, electricity and facility works, but this study is focused upon the building works. The SS1 building has 19 building works, while the rest including SS2, RC1&2 has 17 works. The analysis also includes emissions from major building materials such as cement, ready-mixed concrete, etc.

2. Input-output Analysis

2.1 Characteristics of the I-O Analysis

The assessment method on the energy consumption and CO_2 emission is classified by data-collecting ways. The most accurate way is to collect data on site, but it usually takes time and labor. Another way is to use pre-collected database with a field survey, but it sometimes needs to heavy survey works and pre-collected database doesn't always supply all the data needed. To compromise this weakness the Input-output Analysis is applied to estimate the amount of the energy consumption and CO_2 emission of goods from a product level to an industry level. Generally, the analysis analyzes the interdependent relationship between industries of building products, material production and energy over the life-cycle of a building. It is also an effective method for assessing the direct and indirect effects against the environment so that it could diminish the limitations of the field-survey method.

The analysis, however, has also some limitations as; 1. The Input-output Table consists of desegregated sectors and the number of sector depends upon the varieties of industries in one country. The Korean I-O table has more than 400 sectors but it is insufficient for assessing a specific product or material. 2. When using the I-O Analysis, the result reflects the average detail of a sector, not the detail of a product itself. 3. the amount of the energy consumed by each own industry is excluded in the analysis. In spite of the weakness of the analysis, assessing the interdependent relationship between the sectors becomes the very effective method to quantify the resources and energy directly and indirectly, required for the life-cycle stage of construction, maintenance and demolition in the building industry.

2.2 Procedure of the I-O Analysis

In Korea, the Input-output Table has been published every 5 years by the Bank of Korea and the table reflects the price when it is established. The final demands could be extracted by the price of building materials using the analysis, and then the amount of energy consumption is estimated from the demands. The procedure used in this paper is as follows;

1st step : to survey the characteristics of a target building

2nd step : to classify the industry sector of the building products and materials

3rd step : to estimate the final demand by construction processes, building products and materials

4th step : to estimate the input amount against the final demand by each sector

5th step : to estimate the input amount of energy industry sectors

6th step : to estimate the energy consumption unit

7th step : to estimate the carbon dioxide unit

2.3 Previous Studies

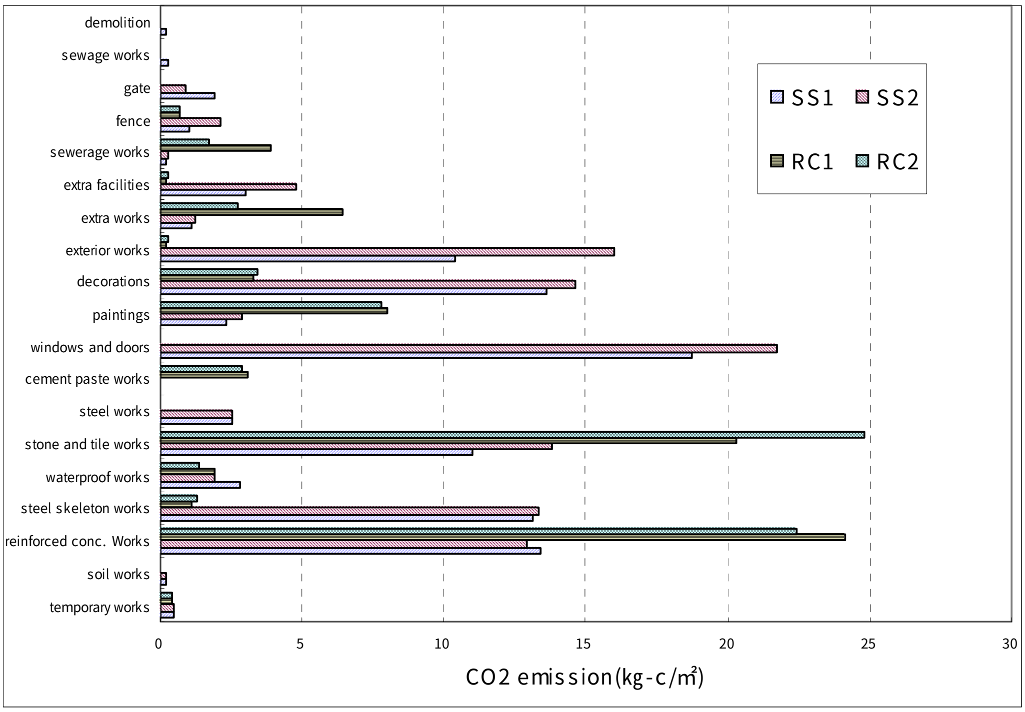
Lots of researches on CO_2 emission of a building have been conducted by various researchers such as Kanji Sakai(1994), Tomonari Yashiro(1994) and J. N. Counaughton(1987), etc. In previous studies, the energy consumption and CO_2 emission of a building were heavy in structural and finishing works than the other works. By building types, the reinforced concrete building showed the mostly heavy emission and then steel skeleton building, masonry and wood building. The major material contribute a heavy emission were concrete, cement and steel.

3. Comparative Analysis on CO_2 Emission

3.1 By Building Works

Every building material is required by each related building work. For instance of a concrete work, ready-mixed concrete and reinforcing bars are needed with steel shoring. To analyze the characteristic of emission by building works, the quantity of building products which are related to building works should be analyzed for estimating the input by industries. Using the input it is able to calculate the amount of energy consumed in the building and then estimate the amount of emission. The amount of emission could be displayed as a unit with dividing the amount by the building areas, shown in Fig 1.

Figure 1 CO_2 emission by building works



In Fig 1, the main works which contribute to CO_2 emission are a reinforced concrete work, a steel work and a windows and doors work, etc. Among the results, the steel building emits CO_2 approximately 2 kg-C/m^2 more than the reinforced concrete building in the structural works as the concrete work and steel skeleton work. In a total, the reinforced concrete building emits CO_2 less than the steel skeleton building, but such important factors affecting the environmental loads as recycling and durability were not considered in this paper. The average of the total emission of CO_2 from the reinforced concrete building is 72 kg-C/m^2, and the steel skeleton building 103 kg-C/m^2. This result means that the steel skeleton building emits CO_2 by 40% more than the concrete building. This result, however, should be limited to these building projects because the four buildings were not designed in consideration of an optimum material application.

Table 2. The amount of CO_2 emission by building works (kg-C/m^2)

Work	SS1	SS2	RC1	RC2	Work	SS1	SS2	SS3	RC2
Temp. work	0.5	0.5	0.4	0.4	Decoration	13.6	14.6	3.3	3.4
Soil and footing	0.2	0.2	0.1	0.1	Exterior work	10.4	16.0	0.2	0.3
Reinforced concrete	13.4	12.9	24.1	22.4	Extra work	1.1	1.2	6.4	2.7
Steel beam assem.	13.1	13.3	1.1	1.3	Facility work	3.0	4.8	0.2	0.3
Waterproof work	2.8	1.9	1.9	1.4	Sewerage work	0.2	0.3	3.9	1.7
Stone and tile	11.0	13.8	20.3	24.8	Fence installation	1.0	2.1	0.7	0.7
Steel work	2.5	2.5	0.1	0.1	Gate installation	1.9	0.9	0.1	0.1
Cement pasting	0.1	0.1	3.1	2.9	Sewage installation	0.3	-	-	-
Windows and doors	18.7	21.7	0	0	Demolition	0.2	-	-	-
Painting	2.3	2.9	8.0	7.8	Total	97.6	109.8	73.8	70.3

3.2 By Building Products

The method to analyze CO_2 emission of building materials and products is similar to the method for building works. In this paper, the amount of CO_2 emission of a product is analyzed by the building area, not by the material weight. In Table 3, the shaped iron and cold rolled iron have higher CO_2 emission property than the other materials in the steel skeleton building, while the ready mixed concrete has higher emission property in the reinforced concrete building. Reviewing the results, the cold iron shows 17.7kg-C/m^2 and the shaped iron 9.5kg-C/m^2 in the SS1 building. The ready-mixed concrete in the SS2 shows 11.3kg-C/m^2 and it is similar to the value of the RC2 building which is 12.6kg-C/m^2. This means that concrete was applied much on slabs in the steel skeleton building and there needs some prefabricated slab for the steel skeleton buildings.

Table 3. The amount of CO_2 emission by building materials (kg-C/m^2)

Material	SS1	SS2	RC1	RC2	Material	SS1	SS2	RC1	RC2
Stone	9.06	12.0	31.7	38.7	Sand & Gravel	0.1	0.2	0.1	0.2
Crushed stone	1.1	1.3	0.9	0.8	Sawed wood	0.1	0.2	0	0
Plywood	3.3	6.0	-	-	Wood products	1.1	1.1	3.7	3.5
Wood furniture	0.3	0.3	0.1	0.3	Paper products	0	-	0.1	0.1
Paint	5.4	5.3	2.0	1.6	Adhesive material	1.2	1.4	0.7	0.7
Plastics	0.3	0.3	0.4	0.3	Industrial plastic	0.7	0.8	6.1	2.2
Industrial glass	5.3	5.8	3.0	3.2	Cement	0.7	0.7	1.3	1.4
Ready-mixed conc.	10.9	11.3	15.9	12.6	Conc. products	0.9	2.0	4.1	2.4
Clay products	1.6	1.4	0.2	0.2	Gypsum plaster	4.4	5.4	0.3	0.3
Asbestos & rockwool	5.0	5.1	-	-	Hot iron	2.1	1.1	3.8	3.9
Steel bar	3.7	4.6	8.8	9.5	Shaped iron	9.5	9.7	-	-
Cold iron	17.7	21.0	4.5	2.9	Steel pipe	0.6	0.6	0.4	0.4
Aluminum	6.5	7.0	6.1	6.2	Construction steel	1.8	2.3	0	0

4. Conclusion

The results show that the steel skeleton building emits more CO_2 than the reinforced concrete building. It consumes energy and emits CO_2 about 40% higher than the other building, when not considering recycling and reuse of resources in the analysis. In the analysis for building materials, the ready-mixed concrete is the mainly contributed material to the environmental impacts among all types of buildings. In detail, the shaped and rolled irons emit the largest amount of CO_2 in the steel skeleton buildings and the ready-mixed concrete and steel bar in the reinforced concrete building. This paper shows that the characteristic of CO_2 emission in the construction stage is varied by building types.

In analyzing the environmental impacts, this paper is focused on the construction stage among the whole life cycle. However, it is required to analyze the other stages to understand the whole environmental properties of a building. Hence, further studies are needed in consideration with a proper scenario of a building including service life, durability, facilities, and so on.

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