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Comparative study on the construction cost including carbon emission cost for masonry walls

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ABSTRACT

Carbon dioxide (CO_2) emissions resulting from construction are one of the main factors causing global warming. It is therefore necessary to make efforts to reduce CO_2 emissions in the construction industry. Although some researchers have studied CO_2 emissions in the industry, there has been a lack of study on the cost of CO_2 emissions. Therefore, this study examines and compares the construction costs, including the cost of CO_2 emissions, of masonry wall types – including common brick, concrete brick, and fired brick walls. The study found that CO_2 emission cost was the highest for brick walls, followed by concrete brick walls. The findings provide information that can be used in engineering methods to determine the cost of CO_2 emissions.

1. Introduction

Main global warming was recognized as a critical issue at the end of the 20th century, and since then, many efforts have been made worldwide to resolve it. The main cause of global warming is the greenhouse gases emitted through the combustion of fossil fuel, which contains the highest amount of CO_2. To reduce greenhouse gases, numerous global efforts have been made, starting with the United Nations Framework Convention on Climate Change at the Rio Summit in 1992. Consistent with the international trend, South Korea, one of the members of the climate change council, introduced the carbon mileage system (CMS) and the greenhouse labeling system.

The construction industry is responsible for more than a quarter of all fossil fuel consumption, and numerous studies have been performed in this industry to actively cope with changes in the internal and external environmental policies [1,2]. Particularly, to estimate the environmental load of building structures, the energy consumption and carbon emissions generated in the entire construction process and the maintenance and dismantling of building structures have been calculated. Further, on this basis, studies have been performed to seek methods to reduce carbon emissions. Kim et al. [1] and Lee and Yang [2] estimated and quantified energy consumption based on the characteristics of construction structures as well as carbon emissions. The energy consumption and carbon emissions were estimated for only a specific amount of construction materials and substances, so it is unreasonable to apply them to a construction project. Building structures involve the use of diverse materials, for which energy consumption and carbon emissions should be calculated separately, because energy consumption and carbon emissions vary for different materials. Moreover, in a construction project, the techniques and materials used are mostly determined by the cost of materials, labor cost, and expenses as per project characteristics and conditions of the construction site. Therefore, the cost of energy consumption and carbon emissions must be calculated separately for every construction project, similar to material and labor costs.

In this study, the cost of carbon emissions generated from each individual material of a wall is determined to enable comparison. We recommend that the cost of carbon emissions be added to the construction cost, which includes labor cost, material cost, and other expenses, to formulate an eco-friendly building structure plan that considers carbon emissions besides the conventional construction cost.

2. Research methodology and scope

The construction process involving energy consumption and carbon emissions can be divided into four phases – construction,

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Nomenclature

CMS	carbon mileage system
ECX	Europe Climate Exchange
EUA	European Union Allowance
EU ETS	European Union Emission Trading System
ICE	InterContinental Exchange
I/O	input/output
LCA	life cycle analysis
TOE	tone of oil equivalent

use and maintenance, dismantling, and disposal of buildings. Of these, in the construction phase, it is most important to encourage an eco-friendly design aimed at reduced environmental load that complies with the climate change council standards, although the use and maintenance and repair phases, which involve maximum energy consumption and CO_2 emissions, are also important. Therefore, the study scope was limited to the carbon emission cost in the construction phase of the school building life cycle.

A building's structure consists of many components, but this study focused on the masonry wall, which is the most commonly used wet wall in Korea for apartment buildings. We considered only three masonry wall types – cement brick, block, and clay brick walls, which are typically used for bearing walls, internal and external partition walls, and decoration. To ensure an objective and accurate comparison, the number and cost of bricks and blocks needed for a 1 m^2 wall were calculated by setting the thickness at 0.5B (half brick), the dimension of the cement and clay bricks at 190 mm × 90 mm × 57 mm, and the dimension of blocks at 100 mm × 190 mm × 390 mm.

We used the following method to calculate and compare carbon emission costs. First, we reviewed studies on energy consumption and carbon emissions and conducted data research to derive the related problems. Second, we reviewed previous studies to examine the method of estimating energy consumption and carbon emissions using the Input–output table (I/O table). Third, the material and labor costs were calculated after determining the quantity of materials and labor needed for each wall. Fourth, based on the material volume used for the estimation, the materials and substances used for each wall type were classified according to the I/O table. This table was applied to the basic unit data of carbon emissions provided in previous studies to determine the cost of estimated carbon emissions based on the costs from InterContinental Exchange (ICE) [3]. Finally, the material cost, labor cost, and carbon emission cost were summed up for each material used in the walls to perform a comparative analysis. Fig. 1 illustrates the methodology of this study.

3. Literature review

We reviewed previous studies before conducting ours. In the construction field, most studies involve quantitative analyses of energy consumption and carbon emissions to present basic unit data using life cycle analysis (LCA), as shown in Table 1, and the energy consumption and carbon emission of individual elements by type, work type, and material using these data. Recent studies have presented applicable methods or proposed programs that may be conducive to decision-making in a construction project.

Kim et al. [12,13] explained the I/O analysis and an accumulation method for the quantification of energy consumption and pollutant emissions including CO_2 from construction activities. Furthermore, they estimated energy consumption and carbon emissions based on construction activity (rebar concrete construction and masonry construction) using the proposed I/O analysis.

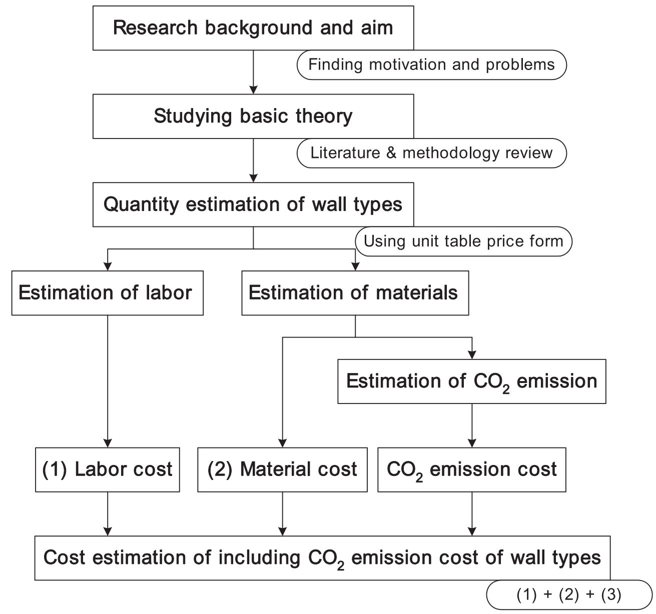

Fig. 1. Research procedure.

Chang et al. [14] developed disaggregated I/O models to calculate the product chain energy of buildings in China. Kimet al. [6] reviewed and re-estimated the basic unit output model for carbon emissions and embodied energy using the I/O table. Moreover, by estimating and presenting the basic unit data based on the calculation of oil and electricity consumed at the construction phase, they established a basic unit database of environmental load appropriate for the domestic market.

In studies on energy consumption and carbon emissions for individual elements, Lee and Chae [15] estimated energy consumption and carbon emissions by construction material/substance and work type using the I/O analysis assuming that construction material and substance input are interrelated with the energy sector at the construction phase. Moreover, at the construction phase of public structures, based on structure type, they estimated the energy consumption and carbon emissions required for the construction material and substance. Kim et al. [12] examined consumption by energy source by extracting samples from office and apartment buildings and presented the basic unit of carbon emissions through their findings. Kim [8] estimated and analyzed energy consumption and carbon emissions by work type, usage phase, and material at the construction phase of apartment buildings, by utilizing the basic unit database of energy consumption and carbon emissions presented in previous studies.

Kim et al. [1] studied program development using the basic unit database of estimated energy consumption and carbon emissions and proposed the properties and composition of the program with which energy consumption and carbon emissions input by phase in the life cycle of building structures. Bourrelleet al. [16] argued an energy payback approach constitute a more adequate way to tackle the environmental challenge net zero energy building. Similarly, while diverse studies have been conducted on energy consumption and carbon emissions, they have analyzed only energy consumption and carbon emissions, and there have been very few studies on determining the cost of carbon emissions especially now when carbon emission credits are being traded.

4. Basic unit calculation method using the I/O table

Input–output analysis, a process assessment technique, is a method that explains economic movement based on the input