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Evaluating the embodied environmental impacts of major building tasks and materials of apartment buildings in Korea

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ABSTRACT

To evaluate the embodied environmental impact of buildings, major building tasks and materials which contribute to these impacts should be analyzed in advance according to the characteristics of buildings and regional environment. Such evaluation, for which techniques are currently being developed, may be used to reduce these impacts. This study aimed to analyze major building tasks and materials in order to evaluate the embodied environmental impacts of apartment buildings in Korea. Six apartment buildings (three types of structure: wall, rigid-frame, and flat-plate) recently constructed in Seoul, Korea were quantitatively evaluated based on a life cycle assessment method in terms of embodied environmental impacts (i.e., global warming, acidification, eutrophication, ozone layer depletion, photochemical oxidation, and abiotic depletion potentials). The results were analyzed based on building tasks and materials according to the structure type of the apartment building. As a result, five major building tasks (reinforced concrete work, masonry work, glass work, plaster work, and carpentry work) and six major building materials (ready-mixed concrete, rebar, insulating materials, concrete bricks, glass, and gypsum boards) were identified, accounting for more than 95% of the values of six environmental impact categories.

1. Introduction

In recent years, strict regulations have been implemented globally to combat increasing environmental pollution that is exceeding the Earth's self-cleansing capacity. Accordingly, sustainable development has been emphasized as an international paradigm, and efforts are being undertaken to reduce the environmental impacts of all industries [1].

One focus of these efforts involves decreasing operational energy consumption of buildings in the construction industry [2,3], which accounts for 32% of total global final energy consumption [4,5] and contributes to more than 70% of life-cycle environmental impacts of conventional buildings [6]. Hence, energy-efficient buildings, such as 3-liter houses, 2000-watt houses [7], and zero-energy buildings [8], which significantly reduce operational energy consumption, are becoming more prevalent [9,10]. However, energy-efficient buildings that only consider operational energy consumption might actually increase the embodied environmental impacts [11]. Embodied environmental impacts are defined as the environmental impact associated with the production building materials, accounting for both resource extraction, processing, and manufacturing, such as the highly efficient insulating materials and windows typically used in these buildings. In addition, as operational energy consumption is reduced by more than 50% using energy-efficient buildings over conventional buildings, the ratio of embodied to operational environmental impacts increases across the buildings' life cycle [12].

Because the importance of embodied environmental impacts is becoming increasingly recognized, case studies are currently investigating both embodied and operational impacts [13–17]. Moreover, techniques for evaluating the embodied environmental impacts of the design stage are being developed to assist in reducing these impacts [18–20]. Two of the main techniques are the Athena Eco Calculator for Building Assemblies developed by the Sustainable Building Institute in Canada and the Life Cycle Assessment (LCA) in Sustainable Architecture (LISA) developed in Australia [21,22]. To conduct such an evaluation, information on the types, quantity, and life cycle inventory database (LCI DB) of the building materials used should be obtained [23]. Because buildings entail more complex processes and require more building materials than do typical products, existing methods of evaluating embodied environmental impacts also involve

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complex structures and procedures [24]. Thus, these methods are rarely used in practical applications, especially in the building design stage because of the excessive time, cost, and manpower requirements [25].

Studies on effectively simplifying these methods have been recently conducted [26], mostly involving the analysis of major building materials representing embodied environmental impacts. However, the evaluation techniques that have been examined are based on the bill of quantities (BOQ) of buildings in North America and Europe, which is calculated using the unit of assembly. For this reason, they do not offer practical applications for Korean construction, where the BOQ is calculated based on the unit of materials by building tasks [27]. Moreover, evaluation results can change according to the construction methods of buildings, characteristics of national geographic environments and construction industry, and LCI DB application methods for building materials [28,29]. To accurately evaluate embodied environmental impacts for buildings in Korea, therefore, major building tasks and materials considering the buildings' characteristics and environments should be analyzed.

This study aimed to analyze major building tasks and materials in order to evaluate the embodied environmental impacts of apartment buildings in Korea.

For this aim, this study consists of the following steps (refer to Fig. 1): 1) goal and scope definition; 2) life cycle inventory analysis; 3) life cycle impact assessment; 4) analysis of assessment result; 5) analysis of major building tasks; 6) analysis of major building materials; and 7) comparison of major building materials. In the goal and scope definition, the six apartment buildings (two wall structures, two rigid-frame structures, and two flat-plate structures) recently constructed in Seoul, Korea were selected as the evaluation targets, and the system boundary was set for the embodied environmental impact assessment. In the life cycle inventory analysis, the drawings and specifications including the BOQ of each evaluation targets were collected, and types of building materials by building tasks were analyzed. In the life cycle impact assessment, embodied environmental impacts of building materials by building tasks were evaluated quantitatively. In the analysis of assessment result, the embodied environmental impact of evaluation targets were analyzed according to the structure of apartment buildings. In the analysis of major building tasks, the major building tasks of apartment buildings were identified based on the assessment results. In the analysis of major building materials, the major building materials of apartment buildings were identified based on the assessment results. In the comparison of major building materials, characteristics of major building materials analyzed in this study were analyzed, and a comparison with major materials analyzed in previous studies were conducted.

2. Methodology

This study analyze major building tasks and materials in order to evaluate the embodied environmental impacts of apartment buildings, which account for more than a third of all buildings constructed each year in Korea [30], based on the LCA methodology.

LCA is a tool for scientifically and qualitatively categorizing resources and energy input, as well as pollutants discharged, during the life cycle of a product or a service and evaluating potential adverse impacts on the environment [31]. It consists of four stages—goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA), and life cycle interpretation—which all have a systematic complementary relationship with one another. In the first stage, a research goal and the scope of the target system are defined. In particular, the following details should be clarified: reason for carrying out the study, intended application, functions of the product system, system boundary, functional unit, allocation procedure, data requirements, assumptions, and limitations. The LCI stage consists of the process flow diagram, data collection, and data calculation processes. Data collection and calculation are used to determine the types of substances impacting the environment in the product system established in goal and scope definition stage. The amounts of inputs and outputs are also quantified. In the LCIA stage, evaluation of potential environmental impacts of the substances listed in the LCI stage is conducted. The LCIA stage consists of classification, the collection of indices of environmental impacts caused by the aforementioned substances; characterization, the quantification of the impacts on

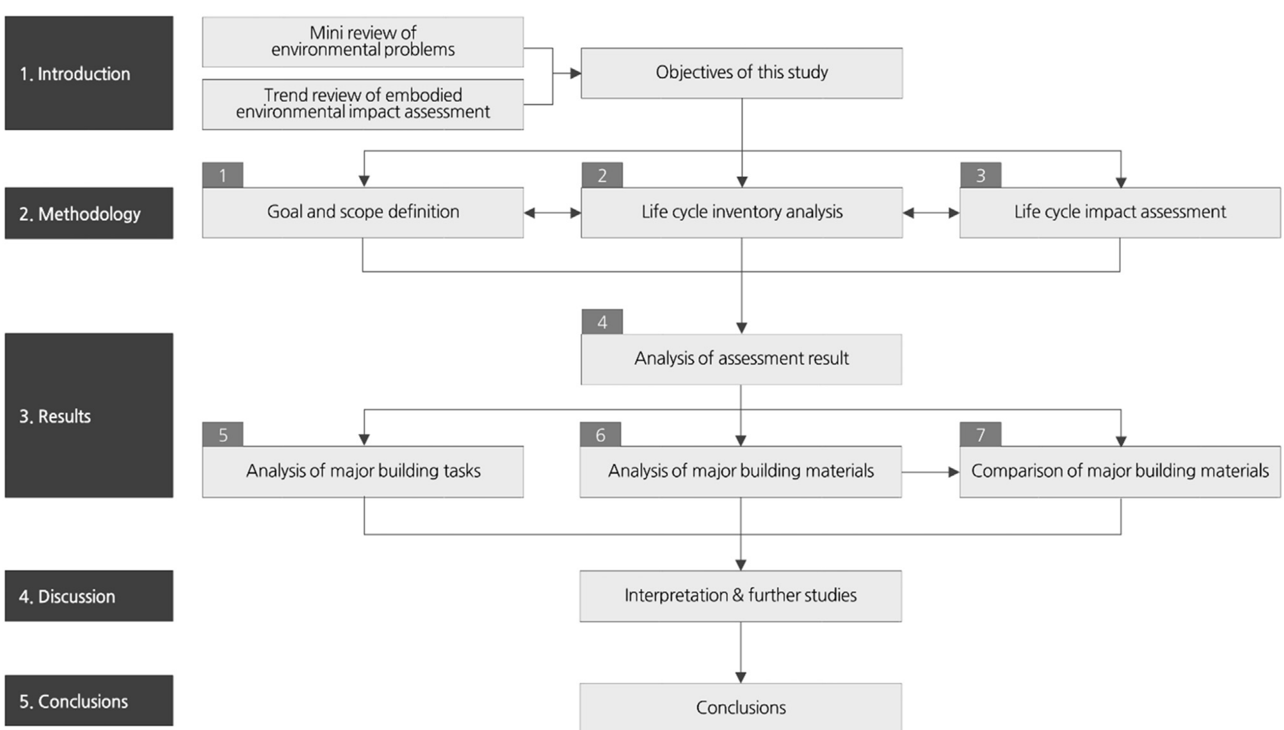

Fig. 1. Composition of this study.