

Research on Sustainability of Building Materials

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Abstract- Sustainable development is one of the most important topics in construction industry. Building materials largely determine the buildings' energy consumption and environmental impacts, and have a significance impact on the sustainability of buildings. Based on the analysis of the environmental impacts of building materials and related academic research conclusions, this research proposes the selection criteria of sustainable building materials for reference.

Keywords- Building materials; Sustainable development; Environmental impacts; Concrete materials.

I. INTRODUCTION

Environmental economics and sustainable development have always been the focus of attention since 1970s and many environmental discussions have focused on the concept of ecologically sustainable development (ESD) [1].

Construction process has a great impact on the depletion of natural resources and greenhouse gas (GHG) emissions caused by fossil fuel combustion, thus affecting global climate change and ozone depletion.

II. SUSTAINABLE DEVELOPMENT OF CONSTRUCTION INDUSTRY

ESD is an efficient use of resources to meet current and future production needs while minimizing adverse impacts on the natural environment. The use of sustainable building materials, which is a way for the construction industry to contribute to protect the environment, has become the key point to minimize the environmental impact and achieve sustainable development.

Achieving sustainable architecture is not to limit the total amount of buildings, but to pay more attention to how sustainable building design and material selection and improve occupants' living condition. Berge (2009) pointed out that the ideal goal for a sustainable future is the reduction and replacement of raw material use, which is especially important

when considering scarce and non-renewable resources. It is also important to reduce waste and loss in material processing, construction and throughout the building's whole life cycle. In addition, the recycle method during demolition must also be carefully planned and regulated, in order to ensure that these materials can be properly disposed and maintained to their original condition rather than being abandoned

III. ENVIRONMENTAL IMPACTS OF BUILDING MATERIALS

The construction industry consumes about 24% of the world's raw materials and a large amount of energy [2]. Conventional building materials like steel, concrete (Fine Aggregate, Coarse Aggregate & Cement) aluminum and glass, are all high-energy materials. The building uses a variety of materials at different stages and the choice of materials used in a building will affect its life cycle performance in turn. Therefore, the designer's choice of raw materials during the design phase can play an important role in the life cycle impact of the building.

Many studies have recognized the importance of material selection, making low-energy materials more considerable than building's operating energy. Choosing materials with high energy consumption will consume more energy in the initial production process and also lead to higher levels of greenhouse gas emissions [3]. However, consistent with the results of Saghafi and Teshnizi (2011) [4], the selection of sustainable building materials may be a harder and challenging task, which reflect the environmental factors of building materials and construction technology. And it is also an unknown area with a large number of variables and uncertainties involved in analyzing and developing the environmental impacts of building materials.

Building materials have an impact on both the building and the natural environment throughout their life cycle. It is essential to select sustainable materials in the early stages of design, establish strategies for sustainable building materials and conduct market research. It is also suggested that the selection of materials will affect the overall performance of buildings, and sustainable building materials

should be considered at an early stage from a life-cycle perspective [5]. The life cycle of building materials is from cradle to grave, which is closely related to the life stages prior to the use of the building, including the extraction of raw materials, the manufacturing and transportation process, and the maintenance and renovation requirements during building operation.

IV. ACADEMIC RESEARCH

The selection of building materials is very important in buildings' life cycle assessment. The criteria of selecting building materials is not only closely related to the overall construction energy consumption in the production process, but also the overall energy consumption in the operating stage. If the material has the potential to be recycled or reused, the construction energy consumption can also be appropriately reduced.

Many studies have confirmed that construction industry consumes the most energy and releases greenhouse gases. With the development of building technology and manufacturing process, the energy intensity of building materials has decreased, resulting in a significant reduction in energy consumption per unit area of production and manufacturing of building materials [6].

Concrete materials are one of the most commonly used materials in the construction area. Studies have shown that the initial construction energy consumption of concrete materials is relatively small while the overall construction energy consumption is very high due to the huge amount of concrete used in buildings [7]. Asif et al. [8] take Scottish dwellings as a prototype to analyze eight types of building materials (wood, concrete, glass, aluminum, slate, ceramic tile, gypsum board, moisture barrier and mortar), and the results show that concrete contributes to the highest energy consumption (up to 61%), and wood and ceramic tiles account for 14% and 15% of the total energy, respectively.

It is also indicated that building materials with low initial construction energy consumption may not reduce the building's whole life cycle energy consumption [9]. For example, although using wood has a positive effect on reducing environmental impacts such as carbon dioxide, some studies show wood will eventually be incinerated or landfilled, and thus will lead to carbon dioxide emissions into the environment [10]. In an LCA study in New Zealand [11], three residential buildings of the same design were analyzed, but the materials used for the structures were different. The results revealed that the initial energy consumption of concrete structure and super thermal insulation building is higher than

that of light structure (wood structure) by 8% and 14% respectively, but the whole life cycle energy consumption of concrete and super thermal insulation structure is lower than that of light structure by 5% and 31% respectively.

Even if the same raw materials are used, the material usage and the internal energy consumption are different through different processing methods [12]. At the same time, building materials with lower initial building energy consumption may not produce lower full life cycle energy consumption. For example, one study conducted LCA analysis on two seven-story residential buildings that also used concrete, but one case used cast-in-place concrete and the other case used precast concrete. Precast concrete slabs have an environmental impact of 12.2% less than cast-in-place concrete, as precast concrete slabs can achieve greater spans between beams, reducing the number of mains and foundations, and reducing the amount of concrete used in the building.

In addition, methodologies such as the reuse of materials such as materials and ecological materials have recently attracted academic attention. Erlandsson et al. [13] studied a new method of recycling materials and argued that if the basic functions are the same, then the strategy of reusing this material is better for the environment than building a new building. Some studies have reviewed the literature on the selection of existing building materials and proposed a simplified method for assessing the environmental load associated with the selection of product materials, i.e., the materials are divided into glass, ceramics, non-ferrous metals, non-ferrous metals, paper, and polymers. And wood, and durable, renewable materials as an alternative, can also promote reuse techniques and methods.

V. CRITERIA FOR THE SELECTION OF SUSTAINABLE BUILDING MATERIALS

Although many research are attempting to solve the problem of material selection, there is no uniform definition of "sustainable building materials" so far. Esin (2007) and Franzoni (2011) [14] points out that sustainable building materials are materials related to resource and energy efficiency in the manufacturing process, and these materials should have little pollution and no negative impact on human health. Abeyundara et al. [15] develops an evaluation matrix to help decision makers balance environmental, economic and social factors in sustainable materials assessment; Anastaselos et al.'s research [16] takes environmental, economic and social aspects into consideration during the thermal insulation evaluation. Therefore, the design standards for sustainable

building materials are mainly divided into the following aspects.

Firstly, sustainable building materials are often natural materials with low energy consumption and low maintenance costs, and should be easily dismantled and recyclable during demolition. The embodied energy consumption of building materials includes initial energy consumption and recurred energy consumption. The former is associated with the energy consumed in the construction phase, and the latter refers to the energy consumption required during the operation phase, including the processes of material replacement, repair and maintenance during the effective life cycle. However, the energy consumption of building materials is not only related to the embodied energy consumption of raw materials recycling and building materials processing, but also related to construction energy and transportation energy during on-site construction. The intensity of energy contained in building materials depends on energy, technology use and manufacturing processes, and will vary from region to region and from manufacturer to manufacturer. Low maintenance requirements could be achieved by the durability of design or repairing existing building materials to extend buildings' life cycle.

Secondly, sustainable materials should be environmentally friendly and reduce environmental hazards without releasing pollutants or other emissions that affect human health and comfort throughout the life cycle. Nowadays, indoor conditions have a crucial impact on the health, well-being and performance of users, as people often spend quite 90% of the time indoors [17]. It is obvious from the research that building materials are a crucial think about determining indoor air quality, among which formaldehyde and other volatile organic compounds (VOCs) released from building materials have serious negative impact on human beings, well-being and productivity [18]. Materials containing pollutants may have negative impact throughout their life span, affecting workers during the assembly process, affecting the occupants of the building during the utilization phase, and causing pollution during recycling and terminal treatment. Therefore, sustainable building materials are materials with low or no emissions of carcinogens, regenerating noxious substances or irritants, and have no negative impact on the building and the natural environment.

In addition, sustainable building materials are mainly derived from renewable energy sources, not non-renewable energy sources. They should also be sustainable throughout their life cycle and use less energy in the manufacturing process.

VI. CONCLUSION

The selection of suitable building materials is an integral part of architectural design as the key point of design is to meet the users' health and comfort needs and to coordinate it with the materials' inherent characteristics. Assessing the characteristics and environmental impacts of building materials is the core of sustainable architecture, and designers are paying more attention to material selection. There will be more opportunities if materials could be taken into account early in the construction stage, i.e. at the development stage of the various codes and work plans.

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