Analysis and Calculation of Carbon Emission Reduction Effect of Prefabricated Buildings

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Abstract: In the context of socio-economic development, the continuous growth of carbon emissions in the construction industry has brought enormous pressure to the improvement of the natural environment. In order for China to achieve its sustainable development strategy better, it is necessary to accelerate the effective application of energy-saving and emission reduction technologies in the construction industry, and improve the effectiveness and quality of construction projects. Therefore, this paper mainly analyzes the factors affecting carbon emissions of prefabricated buildings and the implementation path of carbon reduction. It aims to provide some reference for the sustainable development of the construction industry.

Keywords: Prefabricated Buildings; Carbon Reduction Effect; Analysis and Calculation

1. Introduction

Currently, there are various problems in the global environment, such as excessive greenhouse gas emissions and energy consumption. These issues have had a certain impact on the sustainable development of various countries. The construction industry is an important pillar industry in China's national economy, which plays a very important role in promoting China's economic development. Prefabricated buildings, as an emerging architectural product; Compared to traditional high energy consumption and high pollution cast-in-place buildings, it has important advantages of low pollution and low carbon emissions, and has gradually become an important means for China's construction industry to achieve energy conservation, emission reduction, and sustainable development. Therefore, studying the carbon emission effects and calculation issues of prefabricated buildings is of great significance for the development of prefabricated buildings in China and the smooth implementation of urban building energy conservation and emission reduction.

2. The Construction Process of Prefabricated Buildings

Prefabricated concrete buildings are composed of internal ventilation systems, external maintenance systems, structural design and installation engineering, equipment management and information management systems, etc. The main parts of each system are integrated with prefabricated components and constructed using reliable connection methods. Prefabricated buildings have many advantages such as excellent quality, high efficiency, and short construction period. This paper mainly analyzes the carbon emissions of buildings during the construction process.

2.1 Production Process of Prefabricated Components

Throughout the production process of prefabricated components, the extraction of raw materials, the production and processing of prefabricated components, and transportation inevitably generate a certain amount of carbon dioxide, and the production of prefabricated components also generates corresponding energy losses. For example, the distance between the raw material extraction site and the prefabricated component production site, project engineering, and the technology of the prefabricated component manufacturer are important factors that need to be considered. According to relevant data, the carbon emissions from raw material extraction to production of prefabricated components once accounted for 80% of the total carbon emissions from the production, transportation, and safety of prefabricated concrete components. Therefore, energy conservation and emission reduction work in this stage is particularly important.

2.2 Transportation Process of Prefabricated Components

The process of forming prefabricated components from the factory to the construction site is called the transportation process. This process will also generate a large amount of carbon dioxide due to energy consumption. For example, the types of vehicles used for prefabricated component transportation, their load capacity, total number of vehicles, and the return coefficient of empty vehicles, among others, can be affected by different transportation methods and routes.It can also affect the carbon emissions generated.

2.3 Installation and Use Process of Prefabricated Components

This stage is mainly the installation stage after the prefabricated components are delivered to the construction site, and the installation personnel need to select the corresponding connection fittings for installation. At this stage, the carbon emissions mainly come from the domestic water and electricity consumption of construction workers. If the management and control of daily necessities and household waste cannot be strengthened at the construction site, it will also exacerbate the impact of carbon emissions. In addition, the service life of prefabricated components can reach 50 to 70 years. In the future maintenance and use process, if residents' awareness of carbon emissions is not effectively improved. If there is insufficient use of green decoration materials, excessive generation of household waste, and waste of water and electricity, it will all lead to an increase in carbon emissions.

3. The Calculation Method of Carbon Emissions

From the perspective of traditional architecture, the entire production process, construction process, transportation process, maintenance and installation process of the building will all produce carbon dioxide, while prefabricated buildings add a prefabricated component production process compared to traditional cast-in-place buildings. Therefore, in the calculation of carbon emissions in prefabricated buildings, it is necessary to increase the carbon emissions of prefabricated components during the production process. Generally speaking, when calculating the carbon emissions of prefabricated buildings, the main approach adopted is to divide the entire construction process of prefabricated buildings into several scattered engineering calculations. This mainly consists of three parts: the production process of building materials (steel, concrete, cement, glass, etc.), the transportation process (railway, highway, waterway, aviation), and the production and installation process (mainly including machinery and equipment that may be used in construction: bulldozers, compactors, cranes, mixers, etc.), as well as the carbon emissions that may be generated by coal, gasoline, diesel, natural gas, and other energy losses during transportation and installation.

3.1 Calculation of Carbon Emissions During the Production Process of Prefabricated Components

During the production process of prefabricated components, it is necessary to use raw materials such as concrete, steel reinforcement, and cement. So, the formula for calculating the carbon emissions of prefabricated building materials during the production process is:

$$P_{21}=\sum_{i=1}^{n} p_i \times q_i \qquad (1)$$

In the formula: pi is the emission factor of the i-th type prefabricated component material, in units of CO2/kg; n is the number of types of prefabricated components, in units of “an/a”; Qi is the consumption of Class i prefabricated components, in kilograms.

3.2 Calculation of Carbon Emissions During Transportation

The transportation process mainly involves transporting fixed production materials, such as building materials and various equipment and machines, to the construction site. Among them, this includes construction waste generated during transportation and transportation incidents that occur on site. The calculation formula is:

$$P_{22}=\sum_{i=1}^{n}(q_i \times s_i \times p_i \times k) \qquad (2)$$

In the formula, si is the mileage of the i-th mode of transportation, in km; pi is the carbon emission factor of the energy consumed by the i-th transportation vehicle, in kg CO2 / (t·km); Qi is the transportation mass of the i-th component, in kg; k is the return coefficient for empty vehicles, usually with a coefficient value of 1 67.

3.3 Calculation of Carbon Emissions During the Construction Process

In addition to transportation, prefabricated components also generate carbon dioxide emissions during construction and installation, mainly due to the consumption of various types of machinery installed and energy such as water and electricity during construction. So, the number of machinery on the construction site, as well as the operating time and energy consumption of construction machinery, will also affect the carbon emissions of prefabricated buildings. The calculation formula is as follows:

$$P_{23}=\sum_{i=1}^{n}(q_i \times r_i \times p_i) \quad (3)$$

In the formula, qi represents the energy consumption per shift of the i-th type of construction machinery, in kg; ri is the number of construction machinery shifts for the i-th type, in units of h; pi is the i-th carbon emission factor for construction machinery, measured in kg CO2 / kg.

4. Related Strategies for Reducing Carbon Emissions in Prefabricated Buildings

According to the above analysis, although prefabricated components in prefabricated buildings increase carbon emissions by one production link compared to cast-in-place buildings, they have significant advantages in overall carbon emissions. Therefore, China can formulate targeted measures from the following aspects:

4.1 To Establish Corresponding Incentive and Constraint Policies

On the one hand, the proportion of carbon emissions generated in the production process of prefabricated buildings is relatively large, from the perspective of carbon emissions during the overall construction process of prefabricated buildings. Therefore, the country should formulate relevant policies, such as tax incentives and various subsidy policies for prefabricated component manufacturers using low-carbon and environmentally friendly materials. This can encourage manufacturers of prefabricated components to actively use low-carbon and environmentally friendly materials for production. At the same time, the country also needs to formulate preferential policies for building projects with efficient identification. This can encourage construction units to use various resources reasonably during the construction and production process, reduce the waste of water, electricity, coal and other resources, and improve building efficiency.

On the other hand, the country should adopt corresponding constraint policies and strictly supervise and manage the manufacturers of prefabricated components. This can encourage manufacturers to actively explore energy-saving and emission reducing production methods. At the same time, for manufacturers with high pollution and energy consumption, they can be forced to reform by increasing taxes, reducing fiscal incentives, and other means. This can promote the healthy development of the entire construction industry.

4.2 To Strengthen Technological Innovation

It is also very important to increase investment in energy-saving and emission reduction technologies during the production stage of prefabricated building construction, and promote their nationwide promotion. Therefore, the country should continuously strengthen the development and innovation of energy-saving and emission reduction technologies, actively introduce advanced technologies from developed countries, and combine with the actual situation of the development of China's construction industry to explore a suitable energy-saving and emission reduction path for the long-term development of China's construction industry. To this end, the country can increase the protection of material innovation patents and energy-saving and emission reduction technology patents in the construction industry, encourage manufacturers and practitioners in the construction industry to actively integrate more new energy, new materials, new ideas, and new technologies into the construction process of prefabricated buildings. For example, research institutions, as the main channel for technological innovation and talent cultivation in the construction industry, play an important driving role in the development of prefabricated buildings. Therefore, the government can promote technological innovation in scientific research institutions by formulating relevant research policies, strengthening research funding subsidies, and emphasizing the protection of intellectual property rights of scientific research achievements. This can further expand the scope of application of energy-saving and emission reduction technologies in the construction industry, thereby better ensuring the actual effectiveness of energy-saving and emission reduction.

4.3 To Develop Energy-Saving and Emission Reduction Construction Plans

In the construction process, the architectural design scheme is the key and soul of the entire project. The reason why prefabricated buildings are used for construction is because they have the advantages of excellent quality and low energy consumption. Therefore, in the process of construction, construction companies should also adhere to the design concept of green buildings and actively combine it with local customs and architectural styles to develop comprehensive energy-saving and emission reduction construction plans. For example, in the process of using prefabricated buildings for construction, enterprises can make reducing energy consumption of buildings one of the key points of construction, and increase investment in environmental protection technology in production, construction, and maintenance processes. This is conducive to improving the utilization efficiency of various energy sources during the construction process and gradually promoting the achievement of energy-saving and emission reduction goals in the construction industry.

4.4 To Strengthen the Application of Environmentally Friendly Materials in the Construction Process

During the construction process of prefabricated buildings, construction companies can also achieve energy conservation and emission reduction by actively using other environmentally friendly materials. For example, construction companies can optimize the roof structure when carrying out roof operations, taking into account different climatic environments and outdoor temperature conditions. It can enhance the ventilation effect of the roof by using green building materials, or adjust the indoor temperature using composite roof surfaces. This can help residents reduce the usage rate of air conditioning appliances, thereby achieving the goal of energy conservation and emission reduction. Furthermore, in addition to meeting the goals of energy conservation and emission reduction, construction companies can also improve the overall seismic performance of the building by using safety components such as steel plates, steel beams, and steel columns. This not only effectively enhances the stability and safety of prefabricated buildings, but also further reduces the construction and maintenance costs of buildings, avoiding high energy consumption and emissions caused by multiple construction operations.

5. Conclusion

Compared with traditional construction projects, although prefabricated buildings can achieve energy conservation and emission reduction through technological means, they have obvious advantages in saving resources, improving energy efficiency, and strengthening environmental protection. Therefore, the country can expand the application scope of prefabricated buildings in construction enterprises in China from multiple aspects such as policy measures, technological innovation, construction scheme design, and application of environmentally friendly materials. This helps to achieve efficient development of prefabricated buildings in China's construction industry.

References:

[1] An Min, Liu Mingfang, Wu Hailin Research on the Carbon Emission Reduction Effect and Mechanism of Prefabricated Building Demonstration City Policies on the Construction Industry [J]. Journal of Environmental Sciences, 2024, 44 (02): 464-476

[2] Ding Xiaoxin, Xu Xizhen, Wang Qun. Research on the influencing factors of carbon reduction in prefabricated components of prefabricated buildings based on SEM [J]. Building Energy Efficiency, 2023, 51 (08): 123-128

[3] Chen Fanglin, Ding Yu, Li Keying. Evolutionary Game Analysis of Carbon Reduction Mechanism in Green Supply Chain of Prefabricated Buildings [J]. Value Engineering, 2023, 42 (10): 39-41

[4] Wang Tiezhu, Zhang Jiayang, Zhao Weixuan, Yang Feihua, Zhang Yinxiang. Establishment of Carbon Emission Model for Prefabricated Buildings and Comparative

Evaluation of Cast in Place Buildings [J]. New Building Materials, 2022, 49 (10): 88-91

[5] Zhao Yu, Sun Siyuan, Liu Lu. A Study on the Driving Factors and Pathways of Carbon Reduction in Prefabricated Buildings [J]. Construction Economy, 2022, 43 (10): 90-95

