

Research Methods of Carbon Emissions

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Abstract. As a pillar industry, the construction industry generates 28% of the total carbon emissions of the whole society throughout its life cycle. Through the carbon emission ratio of the whole life cycle of existing buildings, it is found that the carbon emission per unit time in the construction phase is the highest among all phases, and the various environmental pollution caused by it is also the most concentrated. In order to achieve low carbon construction and reduce environmental pollution, relevant parts of the country have promulgated building construction management documents since 2007. The documents put forward clear requirements for green and low-carbon urban and rural construction to ensure green and low-carbon construction activities. It can be seen that in the context of the "two carbon" strategy, carbon emission monitoring and carbon emission reduction of construction have attracted wide attention from all walks of life. In this paper, through the analysis of carbon emission monitoring methods of construction projects, a carbon emission calculation model based on carbon sources and sinks of the construction process is established to realize the quantitative calculation of carbon emission in the construction phase of construction projects. It also establishes a carbon emission monitoring method for the construction phase of the construction project, which provides practical guidance for the carbon emission data monitoring of each construction project and guides the real-time monitoring of carbon emission during the construction phase of the construction project.

Keywords: Monitoring methods, carbon emission, construction projects.

1. Introduction

With the continuous improvement of residents' living standards and the rapid development of the economy, global climate change has become the biggest threat facing mankind. Excessive emissions of greenhouse gases have increasingly intensified the global warming trend, and have caused extremely serious harm to both the ecological environment and the global economy [1]. In order to solve the global environmental crisis caused by excessive carbon emissions, countries worldwide are contributing their strength to carbon emission reduction. As one of the world's largest carbon emitters, China has also taken an active part in the carbon emission reduction action. In September 2020, at the 75th UN General Debate Conference [2]. On the board, General Secretary Xi Jinping made a national commitment to address climate change: "strive to peak carbon dioxide emissions by 2030 and achieve the goal of carbon-neutrality by 2060". In December 2020, General Secretary Xi Jinping set the emission reduction target for 2030: China's dioxygen per unit of GDP by 2030 [3]. Carbon emissions will be reduced by more than 65% compared with 2005, and the proportion of non-fossil energy in sub-energy consumption will reach about 25% [4].

The construction industry, as a pillar industry, accounts for 28% of the lifetime CO₂ emissions for the whole society, while the CO from construction activities accounts for 40% of the CO₂ and emissions from municipal waste. Compared with the carbon emission in the whole life cycle of existing buildings, it is found carbon that the emission per unit of time in the construction stage is the highest in each stage. Environmental pollution, such as noise and dust pollution, are also the most concentrated [5]. In order to realize the building low carbon construction and reduce environmental pollution in the construction process of construction, since 2007 the Ministry and the State Council General Office have issued the construction engineering construction site management regulations, the technical specification for prevention and control of urban dust pollution, "opinions on promoting the development of urban and rural construction green", "about complete and accurate fully implement the new development concept of solid carbon peak carbon and work opinion" and other

documents. These documents put forward clear requirements for green and low-carbon construction and guarantee green and low-carbon construction activities. It can be seen that in the context of the "double-carbon" strategy, building construction, as a short-term activity with extremely high carbon emissions, has received wide attention from all walks of life for its carbon emission monitoring and carbon emission reduction.

The construction phase of a building project is a process in which manpower, materials, machinery, energy and technology are put into the project construction are reasonably organized in time and space according to the relevant standards through a series of activities according to the architectural design documents, construction organization design or construction scheme, and become a building entity [6]. The carbon emission in the construction stage of a construction project shall include the carbon emission generated in the construction process of each branch and item and the carbon emission generated in the implementation process of each measure project. In order to deepen the understanding of carbon emissions in the construction phase of construction projects, this section first analyzes the sources of carbon emissions in each project, and then defines the calculation range of carbon emissions.

2. Monitoring methods

Similarly, in the field of dual-carbon research, the carbon emission and carbon emission reduction of construction projects have become a research hotspot. China has established a relatively mature method system for measuring and predicting energy consumption and carbon emission in the operation stage of buildings [7]. Various researchers and scholars and institutions have monitored and calculated the total carbon emission in the whole life cycle of buildings, and reached a theoretical consensus on carbon emission accounting. However, there is little research on low-carbon buildings in the construction stage, and few studies on carbon emission monitoring method. Existing carbon emissions monitoring methods such as simulation method, machine learning, visualization method of mechanical class, quantities and other construction data acquisition is through the bill of quantities and consumption quota. These cannot really reflect the on-site construction conditions and site management level, so cannot accurately monitor construction carbon emissions [8].

2.1. Research methods

2.1.1. Study Methods

1) Literature analysis method

By collecting and consulting papers, yearbooks and works, on the one hand, we can comprehensively understand the research status and research dilemma of carbon emission in the construction stage of construction projects at home and abroad, and clarify the research basis and the research direction in the construction stage, so as to lay a solid foundation for further research.

2) Web-crawler method

The relevant research results and practical results in the construction stage of domestic and foreign construction projects were obtained through the network crawler method. By sorting out and cleaning these information and data, the mainstream carbon emission calculation model, carbon emission monitoring methods and carbon emission reduction strategies at home and abroad were summarized and sorted out, and further analysis and research were made.

3) Field research method

Through field investigation, define the time boundary of the calculation of construction phase (including measurement line, earthwork excavation, concrete pouring, etc., until the top acceptance) and space boundary (including construction project site planning red line and construction workers living area, etc.), combing the construction process of construction stage and machinery used, and the construction data of low carbon pilot project for field measurement.

4) Expert interview method

Through with the construction engineering construction field, green building, carbon emissions calculation field related to the subject of experts and scholars exchange interview, clear construction project construction stage concept of carbon emissions and connotation, clear the key parameters of construction engineering construction process carbon emissions, and for the construction project construction stage carbon emissions calculation model and monitoring method to provide perfect opinions.

5) Qualitative analysis method

Through the qualitative analysis method of domestic and foreign research on the construction phase of carbon emissions are summarized, such as the carbon emissions calculation model in accordance with the "bottom-up" and "top-down" two kinds of thinking, carbon emissions monitoring method in accordance with the "based on fuel" method and "based on emissions" method two ideas, the carbon reduction way according to the "carbon reduction" and "increase" two kinds of ideas, etc.

6) Case analysis method

Through the selection of Nanjing representative construction project to carry out the pilot study, calculate and monitor the construction stage of carbon emissions, constantly test and improve the relevant technical achievements, provide objective real data support, at the same time further develop specific construction engineering construction stage carbon reduction strategy, provide reference examples for other of the same type of construction engineering.

7) Comparative analysis method

By comparing and analyzing the existing carbon emission-related research results of construction projects at home and abroad, Clarify the current research deficiencies and research difficulties, To determine the research direction, content and method of this topic; By comparative analysis of the existing carbon emission calculation model and monitoring methods, Combing out the advantages and disadvantages, scope of application and applicable conditions of each model and method, So as to provide ideas for the establishment of carbon emission calculation model and monitoring method in the construction stage; By comparing and analyzing the carbon emission data of several pilot case projects, Combing out the carbon emission characteristics under different building types, different construction conditions and different emission reduction approaches, Thus supporting the development of carbon emission reduction strategies.

8) Scenario analysis method

By setting the economic benefits, environmental benefits, economic environment coupling more combination scenario, explore the construction project construction stage under different constraints development trend, analyze the actual effect of different carbon emission reduction way, to the application of different carbon emission reduction strategy construction project carbon emissions prediction.

9) Carbon emission factor method

Through the field measurement of the construction phase of the mechanical equipment actual energy consumption, build construction machinery factor library, thus according to the bill of quantities, construction engineering construction parameter and carbon emission factor database for carbon emission calculation, with specific construction activity data and carbon emission factor product as the value of carbon emission.

2.1.2. Carbon emission calculation approaches

1) Measurement method

The method directly measures the carbon emissions generated by the activity accurately. This method can reduce the intermediate link and carry out more accurate statistics on carbon emissions, but it is often difficult to obtain data, consumes more manpower and material resources, and has high measurement cost. Field measurement is usually carried in the continuous monitoring system of flue gas emission (CEMS) carbon emission monitoring module, through continuous monitoring of concentration and flow rate directly measured its emissions [9]; Off-site measurement refers to the process of collecting samples and sending samples to relevant monitoring departments for

quantitative analysis by using special testing equipment and professional technology. Compared with the two, the accuracy of field measurement is obviously higher than that of off-site measurement because of the adsorption reaction and dissociation of sampled gas during off-site measurement. The formula of measurement method is shown in following equation:

$$G=K\times Q\times C \quad (1)$$

Where: G represents the emission of a gas; Q represents the medium (air) flow rate; K represents the concentration of a gas in a medium; C represents the unit conversion factor in the formula.

From the current situation of using this method, due to its high measurement cost and high measurement requirements, the popularity is not high, and it is suitable for the key emission units with concentrated emissions and high emission intensity, such as thermal power plants. There are many components of building carbon emissions, complicated emission modes and a long emission cycle, so it is difficult to carry out real-time monitoring of carbon emissions in the whole life cycle. Moreover, high technical cost also makes it difficult to adopt this method to calculate carbon emissions in the construction industry on a large scale.

2) Mass balance method

As a new approach proposed recently, its basic principle is the law of conservation of mass, which states that the mass of materials put into a system or device must equal the mass of materials produced by the system. This method has the advantage of reflecting actual emissions in the place wherever they occur. In addition to differentiating between different types of facilities, it can also distinguish individual devices and parts of devices. This method is especially handy when equipment is continuously being updated between different years. It requires less manpower and material resources and costs less, but the data acquisition is difficult, the intermediate process is many, easy to make mistakes. At present, the methodology of this method is not unified, and there are many specific operation methods. It is suitable for frequent replacement of emission equipment and complex natural emission sources.

The formula for calculating CO₂ emission by mass balance method is shown in Equation:

$$E=(Q_y\times C_y-Q_c\times C_c-Q_f\times C_f)\times K \quad (2)$$

Where: E represents CO₂ emission; Q_y represents the input of raw materials, C_y represents the carbon content of raw materials; Q_c represents the product output, C_c represents the carbon content of the product; Q_f represents the output of waste, C_f represents the carbon content of waste; K represents the conversion coefficient of carbon to CO₂ (i.e., the relative atomic mass of CO₂/C, take 44/12).

This method is a theoretical estimation method, which is especially suitable for the estimation of pollution sources that cannot be measured, especially in the process of industrial production, such as emissions from the desulfurization process, chemical production enterprises and other non-fossil fuel combustion processes. In the calculation of building carbon emissions, such methods are not applicable because it is difficult to comprehensively consider and quantify various input materials and output results, and operation energy consumption is difficult to be expressed in the form of products.

3) The emission-factor method

The emission-factor method is the first carbon Emission estimation method proposed by IPCC. Its basic idea is to construct its activity data and emission factors for each emission source according to the carbon emission inventory list, and take the product of activity data and emission factors as the carbon emission estimation value of the emission project. The calculation method is simple, clear and easy to understand, but the carbon emission factor pool is very different, and it requires high regional and timeliness, so it is suitable for the situation where the natural emission source is not very complicated.

Under this method, the calculation of carbon emission can be divided into two important parts, namely, the accounting of activity data and the establishment of carbon emission factor database. Activity data refers to the amount of production or consumption activities that lead to greenhouse gas emissions, such as fossil fuel consumption, electricity consumption, etc. Carbon emission factor is the coefficient corresponding to activity level data, representing the carbon content and oxidation rate of unit activity data, and representing the greenhouse gas emission coefficient of unit production or consumption activity. The emission factor method formula is shown in equation:

$$E=AD\times EF \quad (3)$$

Where: E represents greenhouse gas emissions; AD represents activity data; EF represents the emission factor. Among them, the activity data mainly come from the relevant national statistics and monitoring data, or survey data and emission source census, etc. The emission factors can either adopt the default values in the Guide or the actual measurement results of authoritative institutions.

Carbon emission factor method is the most widely used in the actual calculation process of carbon emission. For example, the Guidelines for the Preparation of Provincial Greenhouse Gas Inventories (Pilot) published by China, the Agreement on Regional Greenhouse Gas Inventories prepared by the University of Manchester, and the Protocol on Greenhouse Gas Emission Methodology published by ICLEL (an environmental NGO). Carbon emission factor method is the most important method to calculate the carbon emission of buildings from the existing building carbon emission calculation standards, the National Development and Reform Commission issued the Greenhouse Gas Emission Accounting Method and Report Guide of Public Building Operating Units (Enterprises) and many other buildings carbon emission calculation standards. In addition, many standards and studies provide factor of carbon emission database to guide carbon emission calculation. For example, carbon emission factor of building materials and transport of building materials are provided in "Carbon Emission Calculation Standard for Buildings", and IPCC emission factor database provides reference value for carbon emission factor of various energy sources. At present, the factor database of the energy has been relatively perfect, which provides the basis for the calculation from the perspective of energy consumption.

2.2. The quantitative calculation of carbon emission

In this study, the calculation model based on constriction process and covering carbon source and carbon sink is established, and the quantitative calculation of carbon emission is realized. This model defines the specific object of carbon emission calculation and the development mechanism in the construction stage, which helps the carbon emission supervision department to carry out scientific and unified carbon emission measurement activities, and also provides quantitative scientific basis for the formulation of carton emission reduction strategies in construction projects [10].

Guide the real-time monitoring of carbon emission in the construction projects. This study constructs the carbon emission monitoring method in the construction stage to provide practical guidance for the monitoring of the data of a construction project.

This monitoring method summarizes the key problems and parameter sources monitoring in construction projects, and forms a list and the carbon emission data list monitoring equipment, which is helpful for the carbon emission supervision department to implement the carbon emission monitoring activities scientifically.

Formulate scenario strategies reduction during the whole construction stage. Based on the existing process flow, this study explores the potential path of carbon emission reduction under specific constraints and different scenarios, so as to provide scientific suggestions for the formulation of carbon reduction strategies. The formulation process of the carbon mission reduction strategy defines the cost input and emission reduction coefficient of each carbon emission reduction measure, sets the constraints such as the carbon emission reduction target, social benefit target and environmental

benefit target, and formulates the carbon emission reduction strategies suitable for various scenarios under multiple scenarios such as the single benefit priority and the coupling of each benefit.

This study guides the two pilot projects under construction, summarizes the experience of the pilot project, formed the construction stage of low carbon control knowledge system, the system by the case of the above project construction process difference, building environment difference of comparative analysis, summarize experience, truly realize the low carbon control knowledge system can fall to the ground, replicable, can be promoted.

3. Conclusion

This study discusses and analyzes various aspects of carbon emission monitoring methods in construction projects. This study establishes a carbon emission calculation model covering carbon sources and sinks based on the construction process and realizes quantitative calculation of carbon emissions. The model clarifies the specific objects of carbon emission calculation and carbon emission generation mechanism, which is conducive to the carbon emission regulatory authorities to carry out scientific and uniform carbon emission measurement activities, and also provides a quantitative scientific basis for formulating carbon emission reduction strategies in the construction phase of construction projects. In addition, this paper establishes a carbon emission monitoring method for the construction phase of construction projects, which provides practical guidance for carbon emission data monitoring of each construction project and guides the real-time monitoring of carbon emissions of construction projects. The monitoring method summarizes the key issues and parameter sources for carbon emission monitoring of construction projects and forms a set of carbon emission monitoring equipment list and data list, which is conducive to carbon emission monitoring activities scientifically carried out by carbon emission supervisory departments. However, the limitations of this study are that it is difficult to anticipate the unexpected problems that occur during the construction of actual construction projects, and these monitoring methods are limited to the construction projects described in the paper.

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