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Carbon Reduction Analysis based on the Whole Life Cycle of Public Buildings

-- A Case Study of a Commercial Building in Tangshan

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Abstract

Against the backdrop of low-carbon policies, taking a commercial building in Tangshan as an example, a 3D model was established using BIM technology. Relying on the Glodon software platform and performance analysis platform, the carbon emission accounting of this single building was completed, and carbon reduction optimization schemes were proposed with analysis on emission reduction effects. The research results show that digital technologies such as the Glodon Building Performance Analysis Platform and Carbon Emission Measurement Cloud Platform have significant advantages in building carbon emission calculation and emission reduction scheme optimization, which can provide data support for energy conservation and carbon reduction in the construction sector.

Keywords

Public Buildings; Carbon Emissions; Carbon Reduction Analysis.

1. Software Technical Background

Glodon's building performance analysis software and carbon emission measurement cloud platform, as professional tools for predicting carbon emissions throughout the entire life cycle of buildings, are widely used in the field of carbon emission accounting. These digital platforms, built on Building Information Modeling (BIM) technology, enable full-life-cycle performance evaluation and dynamic optimization of energy-saving design schemes.

The building performance analysis platform can conduct high-precision simulation and visual analysis on key performance indicators such as building ventilation, lighting, air conditioning, and elevator energy consumption, thereby completing the prediction of carbon emissions. In addition, through the collaborative use of data obtained from the building performance analysis platform and the carbon emission cloud platform, a closed-loop management system for the whole-cycle carbon emissions featuring "simulation prediction - real-time monitoring - dynamic optimization" can be established [1].

With the application of this technology, carbon emission data of buildings at different stages can be obtained. Moreover, the function of comparing multiple carbon reduction schemes provides data support for building carbon reduction, clearly presenting the carbon reduction data of different schemes and quickly identifying the optimal energy-saving strategy. From the perspective of the development of the construction industry, the promotion and application of Glodon's digital platforms have optimized the traditional carbon accounting process in construction and provided technical support for the low-carbon transformation of the construction industry.

2. Project Case

2.1. Project Overview

Against the backdrop of the "dual-carbon" goals, the low-carbon transformation of the construction industry is an inevitable trend. A building project in Caofeidian District, Tangshan City, is located in the northeastern part of the North China Plain, a typical cold climate zone, where the heating period exceeds 150 days. Since the building uses an original coal-fired boiler for heating, the energy consumption for heating accounts for a relatively high proportion, which poses special challenges to carbon reduction work for buildings in this area [2]. In response to this situation, studying building carbon reduction schemes suitable for cold regions is not only of great significance for achieving the "dual-carbon" goals but also can provide reference value for the sustainable development of the construction industry.

This study takes a single commercial building in Caofeidian District as the research object. The building covers a land area of 5,946.73 square meters, with a total construction area of 8,766.470 square meters and a building height of 16.75 meters. It adopts a frame structure, with a seismic fortification intensity of 7 degrees and a designed service life of 50 years. The main body of the building consists of three floors above ground and one floor underground. In terms of building material selection, the roof uses 80mm thick extruded polystyrene boards, the floor slabs are made of reinforced concrete, the walls are self-insulating block walls, and the external windows are side-hung aluminum alloy heat-insulating windows combined with 12A+6LOWE glass.

2.2. Calculation Results of Carbon Emissions in the Whole Life Cycle

For this single building, a 3D architectural model was established using BIM modeling technology, and Glodon's building performance analysis platform and carbon emission measurement cloud platform were employed to calculate the full-life-cycle carbon emissions of this public building and simulate different carbon reduction schemes [3]. Starting from various aspects such as architectural scheme design, building material transportation, and equipment consumption, formulating targeted carbon reduction measures plays a decisive role in reducing building energy consumption and carbon emissions [4].

In this study, a 3D architectural model was built using BIM technology, and based on the model, the accurate quantities of sub-projects such as masonry, doors and windows, concrete, and machinery were calculated by aggregation. For the calculation of carbon emissions from building material transportation, in strict accordance with the Standard for Calculation of Building Carbon Emissions (GB/T 51366-2019), the benchmark transportation distance for concrete was set as 40 kilometers in Glodon's performance analysis platform, while the default transportation distance for other building materials was 500 kilometers. Based on key parameters such as the usage of building materials and transportation distance, the platform can accurately calculate the corresponding carbon emissions through its built-in algorithms. For the energy consumption analysis during the operation stage, accurate parameters were set in the software according to the design drawings and relevant installation specifications [5].

In Glodon's performance analysis platform, Caofeidian District is set as a severe cold region. After inputting data parameters such as relevant building material transportation distances, carbon emission factors, and transportation vehicles into the professional software system, carbon emission data analysis of the building in different life cycle stages can be obtained, ensuring the digitization and comparability of data in each stage [6]. This digital calculation method provides reliable technical support for carbon emission accounting in the construction industry and significantly improves calculation efficiency and accuracy.

The research results after inputting data parameters and corresponding engineering quantities show that the material production and transportation stage generates 13,300.676 tons of

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carbon emissions due to the use of high-energy-consuming building materials such as concrete and steel bars, as well as the fuel consumption of heavy transport vehicles. Carbon emissions during the construction stage mainly come from energy consumption of machinery operation, material processing, and the establishment of temporary facilities, with a calculated carbon emission of 346.276 tons. Due to long-term consumption of energy such as electricity and heat, as well as the need for regular maintenance of different equipment during the operation stage, the carbon emissions in this stage are as high as 91,777.156 tons, accounting for 82.35% of the total emissions. This highlights the problem that energy consumption in the operation stage of buildings in cold regions accounts for a relatively large proportion. The carbon emissions in the demolition stage when the building is discarded are relatively low, at 273.444 tons.

Table 1. Unoptimized Building Carbon Emission Calculation Report

category	carbon emissions (tCO2)	building area (m2)	carbon emissions per unit area (kgCO2/m2)
the stage of building materials production and transportation	13300.676	8766.470	1517.221
construction stage	346.276	8766.470	39.500
operation stage	91777.156	8766.470	10469.112
demolition stage	273.444	8766.470	31.192
sum	105697.552	8766.470	12057.025

2.3. Analysis of Carbon Reduction Optimization Schemes

In the process of building carbon reduction optimization, this project focused on optimizing the building material transportation stage and the operation stage. During the operation stage, materials were sourced locally; for example, materials such as concrete and steel bars were procured from the area where the project is located. It is estimated that this adjustment of transportation distance reduced fuel consumption in transportation, thereby cutting carbon emissions by 227.49 tons. This result indicates that shortening the distance for building material transportation is one of the effective ways to achieve carbon emission reduction in buildings.

To address the issue of high carbon emissions during the building's operation stage, the traditional coal-fired boiler was replaced with a ground-source heat pump heating system. The ground-source heat pump heating system achieves zero direct carbon emissions by utilizing underground thermal energy for heating [7]. Data from the software comparing carbon emissions from coal-fired boilers and ground-source heat pump systems for heating shows that the annual carbon emissions are reduced by 8,212.1 tons, and energy efficiency is improved by more than 3 times, providing a feasible low-carbon heating solution for buildings in cold regions.

This commercial building uses central air conditioning for cooling in summer. The central air conditioning refrigeration system generates a large amount of carbon emissions during operation. By upgrading the central air conditioning equipment, an intelligent temperature control system was adopted to dynamically adjust the cooling capacity according to actual needs; the original R407C refrigerant was replaced with HCFC-22 refrigerant, which has a lower greenhouse effect. After the transformation, the energy consumption data of the system has significantly decreased, enabling effective control of greenhouse gas emissions.

In terms of elevator system renovation, the project has introduced intelligent energy-saving elevators [8]. Their working principle is to reduce invalid operation through variable frequency speed regulation and intelligent dispatching technologies, thereby achieving carbon reduction effects. Data from the optimized platform shows that the new elevators have reduced energy consumption by 30%-40%, with an annual carbon reduction of 1,639.152 tons, realizing low-carbon operation of the vertical transportation system.

Using renewable energy technologies, photovoltaic panels are installed on the building roof to convert stored solar energy into electricity, with an expected annual carbon reduction of 4,584.156 tons. Meanwhile, taking advantage of favorable terrain, coastal areas rich in wind energy resources are equipped with wind turbines, expecting an annual carbon reduction of 3,537.2 tons. The collaborative application of these two clean energy sources can generate a large amount of electric energy, significantly reducing the building's dependence on traditional power grids[9].

In terms of environmental optimization, the rational configuration of arbors, shrubs, and lawns forms a carbon sink capacity of 107.9 tons. These green plants not only beautify the environment and enhance commercial quality but also continuously absorb carbon dioxide through photosynthesis, achieving a win-win situation between ecological benefits and commercial value.

Table 2. Carbon Reduction Analysis Summary Table

Stage	Emission Reduction Measures	Reduced Carbon Dioxide Emissions Before Optimization (Unit: Ton)
Building Materials Stage	Choosing nearby material sourcing in the building materials transportation stage, greatly shortening the building materials transportation distance	227.49
Operation Stage	Using ground - source heat to reduce energy consumption and lower carbon emissions	8212.1
Operation Stage	Replacing R407c refrigerant with HCFC - 22 refrigerant	181
Operation Stage	Replacing smokeless coal with natural gas for domestic hot water	9530.062
Operation Stage	Replacing ordinary elevators with intelligent energy - saving elevators	1639.152
Operation Stage	Using photovoltaic power generation technology	4584.156
Operation Stage	Using wind power generation technology	3537.2

3. Conclusion

Through the engineering application of this project and the analysis of different carbon reduction strategies, it is found that implementing standardized emission reduction measures can significantly reduce building carbon emissions. The relevant calculation data provide important reference for formulating targeted carbon reduction schemes for this project, and also verify the practical application value of digital technology in building carbon reduction. This achievement not only provides data reference for the low-carbon transformation of the current project, but also accumulates valuable experience for energy conservation and emission reduction work in similar buildings.

This study has completed the carbon emission prediction and carbon reduction assessment of single buildings by innovatively integrating carbon reduction technologies, energy-saving technologies, and digital means, relying on the Glodon software platform and performance analysis platform. The optimization results show that this digital platform has significant advantages in building carbon emission calculation and emission reduction scheme optimization, providing reliable data support for green buildings in design optimization, construction management, and operation maintenance.

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