The Building Material Use Study of the Eco Learning Camps Design for Elementary and Middle School Students: A Case Study

Qiqi Liu, Chenghao Zhu, and Xin Wu*

***Abstract*—The design of Eco Learning Camps (ELC) for primary and secondary school students endeavors in building individuals' awareness to care for the environment through environmental-based value education. Against the backdrop of achieving China's goal of carbon peaking and carbon neutrality, it seems to be an urgent task to answer the question of how to reduce the carbon footprint of buildings in the design and operation of ELC. This paper selects the camp of ancient dragon kiln in Huangshi Village, a village in Fuzhou City, Fujian Province, as a case study for design and research. Comparing with relevant cases, it finds out that the carbon footprints of different building materials used in the existing Eco educational buildings are much lower comparing with the traditional building materials. The results of this study show that carbon emissions can be significantly reduced by replacing the main building materials of the camp. On this basis, this study proposes the four major design strategies that need to be followed in the selection of materials for the design of ELC.**

***Index Terms*—Eco learning camp, carbon footprints, building material use**

I. Introduction

The policy of promoting study tours was firstly proposed in 2013 as an important element of China's quality education and a good vehicle for bridging school education and extra-curricular practice by China's National Tourism and Leisure Programme Law (2013–2020). Since then, study tours have become a mandatory curriculum activity for school students aged 7–16. On 22th September 2020, President Xi Jinping of China proposed to achieve "carbon peaking by 2030 and carbon neutrality by 2060", which opened a new journey towards the era of carbon neutrality for China. The construction industry, as one of the main carbon emission sectors, has a great mission in this process. Against this backdrop of carbon peaking and carbon neutrality, it thus seems to be an urgent task to answer the question of how to reduce the carbon footprint of buildings in the design and operation of Eco Learning Camps (ELC) for primary and secondary school students which endeavors in building individuals' awareness to care for the environment through environmental-based value education.

At present, extensive research have been carried out to discuss the carbon emissions accounting of building materials according to time, space or energy sources [1]. A parametric model, developed for carbon emissions throughout the life cycle of the building showing that the carbon footprint is proportional to the energy footprint, which provides an in-depth analysis of how carbon emissions can be minimized during the life cycle of a building [2]. However, it seems that there is still insufficient research on the carbon footprints of different building materials. Therefore, this study summarizes and refines the current proposed carbon accounting methods to identify design methods and strategies that can reduce an ELC's carbon emissions. It is hoped that the calculation method could provide a feasible and more practical method for different building materials, which has not only theoretical value but also practical for designing ELC.

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II. Literature Review

A. Carbon Accounting Methods

To reduce an ELC's carbon emissions, the literature study has to fulfil two objectives. Firstly, to find the most appropriate accounting methods by a thoroughly literature study on the carbon emission accounting methods. Secondly, to understand the impact of the different design, construction and material choices on carbon emissions by case studies.

The accounting of carbon emissions can be divided into two groups: the microscopic accounting of individual buildings and macroscopic accounting of regional buildings. The educational nature of the ELC building makes it different from other public buildings. In addition to meet the basics a public building is intended, it has to meet the needs of accommodation, which are more concentrated and intermittent than ordinary youth hostels. As such, a universal approach was taken to examine the carbon accounting methods for educational architecture.

The key part of a single building's carbon emission accounting focus on the model construction, which varies according to the green building evaluation system chosen. The US LEED system, as Wang and Cui [2] summarizes, evaluates individual buildings at four levels. The British BREEAM system, however, concerns more the energy consumption and CO_2 emissions of buildings and uses the whole life cycle of building carbon emission counting approach, and contains nine parts from land use to the layout and energy consumption. Its assessment links building energy consumption and carbon emission indicators [3]. Nevertheless, both LEED and BREEAM evaluate more the energy-efficiency in green buildings and their environmentally friendliness, but lacking attention to carbon emissions by specific CO_2 emission indicators [4]. Li and Zhu [5] suggests that China has referred to and introduced a

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series of accounting systems, such as the BEPAS of Tsinghua University and the Carbon Emission Standard, which mainly focus on different stages and structural forms of buildings for accounting and comparison; South East University (SEU) has launched the Donghe Building Carbon Emission Calculation and Analysis Software, which introduces blockchain to build a BIM model to visualize the whole process of carbon emissions [6]. By studying domestic micro carbon emission accounting methods, we found that despite the fact that some of the research methods in China introduce more advanced tools for calculation, problems such as short coverage period and weak analyses of building functions still need to be solved.

In a calculation study of carbon emissions of individual buildings, Qin and Yuan *et al.* [7] focused on the whole life cycle carbon emission of the metro stations of Chengdu Metro Line 3, and divided it into four stages: production of building materials, transportation of building materials, construction operation and usage. in the production phase of building materials and the operation phase, each building in a metro station emits about 41% and 51% respectively per centage of the carbon in its whole life cycle of 50 years. In case its life span extended, the operation phase carbon emissions would increase gradually and reaching 67% at 100 years, while the proportion of carbon emissions in the production and transportation of building materials, and construction phases would decrease to 33%. The share of the physical process in the total life cycle of a building is apparently significant in quantitative calculations. Therefore, it is necessary to strengthen the low-carbon evaluation of the two main building materials, steel and concrete, and choose building materials that can reduce carbon emissions during the production phase of building materials, and thus reducing the carbon emission index of the whole life cycle of a single building and improving its low-carbon level. Through the study of the more extensive green building carbon accounting methods, the author clarifies the common calculation methods as well as relevant case studies.

B. Low Carbon Materials

For education buildings, Cui and Zhou [8] suggests that universities have great potential to control carbon emissions, and proposes corresponding accounting methods and rectification methods in terms of usage time, centralized management and layout. The design of education buildings can be focused on specific time periods, as they are mainly targeted at students and teachers, and their activities are concentrated. However, the methods proposed are mainly for the control of operational carbon emissions, and there is a lack of methods for the control of carbon emissions during the design process of the building. In the design of the gymnasium of Yancheng Junior High School in Wujin District, Changzhou City [9], Lan [10] used timber structures to control the overall building carbon emissions, while introducing BIM technology in the design process to enable energy saving in the building assembling process. Wood is a renewable material and timber structures are very low carbon and clean construction in comparison with steel and concrete structures. The water pollution index of steel structures is 120 times higher than that of wood structures. Wood structures are 8% to 16% more energy efficient than concrete structures, and each cubic metre of wood will store 0.9 tons of CO_2 equivalent, while 1.1 tons of carbon emissions can be reduced during the wood manufacturing phase [10] while introducing BIM technology in the design process could save energy during the assembling process.

Comprehensive literature above shows that most of the carbon emission accounting of education buildings mainly focuses on the operation stage of the buildings, and the primary method to achieve green and low carbon is through the environmental design of the campus. The design and construction of education buildings is also an important part of the life-cycle carbon accounting. In the process of designing a learning camp, the above two aspects need to be combined and the design needs to be tailormade to the characteristics of the campus building, and the building materials needs to be carefully chosen in the design and construction process. Most current studies focus on the use of the building itself, with very few research can be found on carbon emissions from the perspective of green building material.

According to the current Chinese Green Building Evaluation Standard, the use of green building materials and material saving play an important part in the evaluation system, with particular emphasis on the importance of using recyclable materials, reusable materials and waste-friendly materials in green buildings. Among the commonly used green building materials such as bamboo, wood, ceramics and fly ash, wood is the more commonly used recyclable material and has a relatively good carbon sequestration effect.

Zhan [11] analyses the good carbon sequestration effect of wood and bamboo structures, which can be combined with the rural vitalization in the subsequent construction process, leading to the revitalization of the rural vitalization and the scientific management of forests. The paper makes it clear that the carbon footprint of wood and bamboo buildings is significantly lower than that of buildings made of other materials, and that the main problem at present is how to achieve a sustainable supply of relevant building materials. As a new form of construction, prefabricated buildings are gradually taking over the market. Chen [12] analyses the superiority of assembled buildings over traditional buildings in terms of carbon emissions, which are mainly reflected in four parts: design emission reduction, production emission reduction, construction emission reduction, and operation and maintenance emission reduction. In the section on production emission reduction, the high level of factorization of assembled buildings compared to traditional construction models can significantly improve the construction process, and its standardized, refined and intensive production mode can give full play to the performance of raw materials and reduce their consumption. For example, the scalable precast concrete construction production line developed by Shanghai Construction can effectively improve production efficiency and significantly reduce energy consumption in the processes of steaming, pouring and demolding.

In the design and construction of prefabricated buildings, Lan [10] used the technology of prefabricated buildings in the design of the gymnasium of Yancheng Junior High School in Wujin District, Changzhou City, which is a single-story, large-span prefabricated building combined with a reinforced concrete frame structure. A large number of prefabricated elements were used in the design process and finely processed using BIM technology, with a prefabricated assembly rate of over 90% for the assembled timber portion of the structure, at a cost comparable to that of a cast-in-place reinforced concrete building. However, due to its finely integrated design, production and management of the life-cycle building system, the energy consumption and carbon emissions of the whole process are greatly reduced. The case study shows that the common building material used for green buildings is wood, and that the use of assembled construction methods during the construction process can effectively reduce carbon emissions.

Through the literature review, this paper identifies the carbon emission calculation methods and practical modeling software that need to be adopted for Gulong Kiln Learning Camp. Since the building was not yet completed, we constructed a refined computer Building Information Modeling (BIM) model based on the existing design and construction situation and design plan of the camp, based on both data analysis and comparative analysis to quantify the calculation of carbon emission during the construction process of the single building design.

III. Research Methodology

This study mainly adopts a case study approach and chooses to discuss in depth the whole life cycle-based building carbon emission evaluation model, which considers and calculates the whole process of building production, construction and demolition, yielding more scientific and rational results. It not only calculates the total carbon emissions of a building, but also incorporates factors such as the life span of the building into the final results.

$$P = P_1 + P_2 + P_3 + P_4 \quad (1)$$

P: Total carbon emissions for the entire life cycle of a low carbon building/kg

P_1: Carbon emissions from the building design phase/kg

P_2: Carbon emissions generated during the building construction phase/kg

P_3: Carbon emissions from the building operation and maintenance phase/kg

P_4: Carbon emissions from the disposal phase of the building/kg

At the same time, as carbon emissions have many optional indicators, the calculation process of many methods is tedious and complicated. The whole life cycle-based building carbon emission evaluation model uses the emission of greenhouse gases (mainly carbon dioxide) as the judgment indicator, simplifying the overall calculation process while being distinctly representative.

For this formula, the main study is how the carbon emissions of the building's construction process should be saved. The carbon emissions from the design process and the operation and maintenance process can be ignored, and the main focus is on the carbon emissions from material delivery, construction and the carbon emissions from the building materials themselves during the materialization process, making the overall calculation convenient and easy. Since the author focuses on the impact of the choice and use of building materials on carbon emissions, the formula can be appropriately adopted.

The equation for the materialization phase of the building is as follows

$$P_2 = P_{2.1} + P_{2.2} + P_{2.3} \quad (2)$$

$P_{2.1}$: Carbon emissions from the building production process/kg

$P_{2.2}$: Carbon emissions from the transport process/kg

$P_{2.3}$: Carbon emissions from the transport process/kg

For the use of building materials, the two building materials with the highest emissions are selected for calculation according to the two-eight principle, mainly the materials of the main building envelope. In the calculation, the value of carbon emission reduction is obtained by comparing the main material replacement of concrete and wood. Therefore, when selecting the main materials of the building, attention needs to be paid to the use of reasonable and material-saving building materials for design, such as bamboo and wood, which can effectively reduce carbon emissions.

At the same time, the choice of this method as the carbon emission calculation method for the learning camp has the specificity of the building function: due to the high frequency of building use and the high flow of people, it leads to the use of large, obvious mechanical devices that are highly disruptive to the activities of the crowd (children) and have a certain degree of danger. This method was chosen as the method of calculating carbon emissions for the learning camp because of the simplicity of the equipment required for carbon emissions measurement and the ease of installation and dismantling.

Since the expected carbon emissions of a building can be effectively calculated at the design stage with digital building modeling, the author used the BIM software to compare the reduction of carbon emissions by changing the building materials.

IV. Data Analysis

In the design process of Gulong Kiln Learning Camp in Changle City, we constructed a refined computer model based on the existing design and construction situation and design plan of the camp, based on two methods of data analysis and comparative analysis. For the calculation of carbon emissions in the design and construction process of the single building carbon emissions, this paper establishes a BIM model in order to complete the quantitative research, specifically by establishing a BIM model of a small education building (student activity center). The author use BIM exporting its material list and making detailed calculations (recorded as Table I), and replacing most of the components in the model with wood for comparative calculations (recorded as Table II), in which the recommended values in the Standard for Calculation of Carbon Emission of Buildings are used for the selection of carbon emission factors for the building materials used, and the calculation results of Chinese scholars are used for the building materials for which the values of carbon emission factors are not given in the standard. By clearly replacing and comparing the main materials, the reduction in carbon emissions can be visually fed back. From the comparison of the two sheets, it is clear that wood can effectively reduce carbon emissions and contribute to environmental protection.

TABLE I: CONCRETE MATERIAL SCHEDULE

Material: Name	Material: Volume	Material: Weight	Counting	Carbon emission factors for building materials	Carbon emissions
Concrete-Precast Concrete-35 MPa	98.3m³	23.6 kN/m³	60	295kgCO_2e/m³	28998.5 CO_2e
Concrete brick wall	347.73m³	23.6 kN/m³	61	336kgCO_2e/m³	166837.28 CO_2e
Wood - Cherry	0.48m³	5.0 kN/m³	24	178kgCO_2e/m³	85.44 CO_2e
Cast-in-place concrete	169.63m³	23.6 kN/m³	12	385kgCO_2e/m³	65307.55 CO_2e
Total					261228.7 CO_2e

TABLE II: WOOD MATERIAL SCHEDULE

Material: Name	Material: Volume	Material: Weight	Counting	Carbon emission factors for building materials	Carbon emissions
Concrete-Precast Concrete-35 MPa	43.45m³	23.6 kN/m³	32	295kgCO_2e/m³	12817.75 CO_2e
Concrete brick wall	0m³	23.6 kN/m³	0	336kgCO_2e/m³	0
Wood - Cherry	514.68m³	5.0 kN/m³	86	178kgCO_2e/m³	91613.04 CO_2e
Cast-in-place concrete	0m³	23.6 kN/m³	0	385kgCO_2e/m³	0
Total					104430.79 CO_2e

BIM technology is an important technology used in the design process of green and low-carbon buildings, and the simultaneous construction of BIM models and the replacement of some of the materials in the design process can largely lead to building construction. Digitalisation of emission reduction.

V. CASE STUDIES

A. Overview of the Case

The site area of the Gulong Kiln project in Huangshi Village is 55308.78 m², with the purpose of setting up dormitories and classrooms capable of serving 500 people, multi-functional halls, etc., capable of accommodating 500 people for activities and short-term stays. The project chosen for this study is the construction of a learning camp for the Gulong Kiln in Huangshi Village, located in Changle City, with an area of approximately 6.3 km² and a population of 5070. Huangshi Village is the largest jasmine industry base in Changle, while Gulong kiln is the only kiln in existense in Changle where pottery is fired and has a special cultural symbol. From the perspective of sustainable educational innovation, Gulong Kiln learning camp in Huangshi Village uses the ancient Gulong Kiln as the centre of its design, which has a strong cultural renewal, and combines ceramic technology with study tours, which also enhances the experiential nature of the learning camp. In addition, the learning camp also contributes to carbon neutrality by retaining most of the surrounding woods to fully absorb the carbon dioxide waste emitted; at the same time, some human waste is used as fertilizer for planting, turning waste into energy and reducing carbon emissions.

According to the data released by the Fujian Province Primary and Secondary School Research and Study Big Data Monitoring Platform (SR and SBDMP, http://yanxue.101.com/jdzs/detail.shtml), the total number of visitors to research and learning camps in the province reached 36,000 in 2018, covering 12,000 primary and secondary schools in the province. It is evident that research and education bases have become a frequently used venue for student activities. In a carbon-neutral future, it is equally important to study how to achieve innovation in the sustainability of research and learn camp for education.

The Gulong Kiln Learning camp in Huangshi Village, Changle City, Fujian Province, is designed as a research object, and under the premise of focusing on the students' living and learning experience in the camp, the education building shoulders the goal of achieving carbon reduction, energy conservation and sustainable design is its exploration as an education building for green low-carbon design.

B. Building Materials Selection

Based on a literature review of green building materials at home and abroad and the original environment of the site, the building materials for the learn camp were selected. Due to the presence of an ancient kiln inside the base and the transformation of it during the design process, a large amount of wood and bamboo plywood was used for the old cultural part, which can effectively reduce the carbon emission of the building. At the same time, the use of assembled construction methods in most parts of the design and construction can greatly reduce the carbon emissions of the whole process and make a corresponding contribution to environmental protection.

As the site itself is located in the countryside, the choice of timber as the main design material makes the building to blend discreetly into the rural context, making it seem to grow out of the local soil and integrate well with the environment. At the same time, it can also drive the rural revitalization and scientific forest management, promoting a refined and orderly process of using wood.

With REVIT, the building modeling software, the carbon emission of the building is effectively controlled from the design stage, and the carbon emission is expected to be reduced by about 100,000–150,000. And since the use of the ELC is time-sensitive, in the off-season when there are no students using it, the ELC will be open to the surrounding residents for their use of the land, which can effectively promote carbon absorption.

VI. CONCLUSIONS AND RECOMMENDATIONS

The green and low-carbon construction of campus buildings is one of the important ways to achieve sustainable development in education, and is also a major focus for achieving carbon neutrality, which is the mission of the construction industry in the process of achieving carbon neutrality. The design process of campus buildings is a complex and systematic study of how to achieve energy saving and emission reduction in the physical process, as well as to reasonably anticipate the possible energy wastage in the use process. Therefore, through the study of carbon emissions of building materials in ELC for primary and secondary students, a simple method of calculating carbon emissions throughout the life cycle of a building is summarized and a design and construction strategy for energy saving and emission reduction of similar educational buildings is gradually derived, so as to promote the sustainable development of education and educational buildings while controlling carbon emissions, and provide a reference for sustainable educational buildings and green low-carbon architectural design. In the study of the impact of building materials on carbon emissions, the reduction in carbon emissions can be visualized through the creation of BIM models. For ELC, its building materials can be used wood, which is not only beneficial to reduce carbon emissions, but also beneficial to environmental integration.

This paper, through the study of carbon emission control of the Ancient Dragon Kiln ELC, an environmental research and study base, reflects that building materials have an important role in influencing carbon emissions, and since the building has not yet been built, the study of carbon emissions from its use is still at a standstill.

Current academic research suggests that the active introduction of green, low-carbon building materials at the design and construction stage of a building is an important way to achieve energy savings in buildings. To better develop eco-building, carbon emission control can be done at the building design stage by changing the building materials, such as using more wood instead of concrete. In addition, the use of assembly methods to complete the building construction process can greatly reduce carbon emissions and contribute to carbon neutrality. Due to the special nature of the ELC, its use has a concentrated time, and in the remaining time, it can assume the rest of the uses and bring into the diversity of the building.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Qiqi Liu and Chenghao Zhu conducted the preliminary research, modeling and thesis writing, while Xin Wu supervised the project and tutored the writing; all authors had approved the final version.

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References

[1] M. Zhao, S.-Y. Wang, W.-B. Kang *et al.*, "A review of carbon emission accounting research in the building sector," *HVAC*, pp. 1–15.

[2] G. Wang and H. Cui, "Exploration of carbon emission calculation and carbon reduction strategies in buildings," *Intelligent Building Electrical Technology*, vol. 16, no. 2, pp. 150–154, 2022. (in Chinese)

[3] Y. Liu, "Building carbon emission evaluation model based on whole life cycle," Dissertation, Dalian University of Technology, 2015.

[4] K. Wang and Y. Ma, "Research on green building evaluation system based on building carbon emission analysis," *Energy Conservation*, vol. 40, no. 8, pp. 75–77, 2021.

[5] X. Li and C. Zhu, "A review of the research on carbon emission accounting and influencing factors of buildings in China," *Journal of Safety and Environment*, vol. 20, no. 1, pp. 317–327, 2020.

[6] "Southeast university launches carbon emission calculation and analysis software for buildings," *Building Materials Technology and Applications*, no. 2, p. 24, 2022. (in Chinese)

[7] A. Qin, Y. Yuan, and F. Jiang, "Study on the whole life cycle carbon emission of subway station building—A station of Chengdu Line 3 as an example," *Construction Economics*, vol. 41, no. S1, pp. 329–334, 2020.

[8] P. Cui and S. Y. Zhou, "Research on carbon emission accounting and carbon neutral pathways in Chinese universities—A literature analysis based on the database from 2008–2021," China University Science and Technology, vol. 10, pp. 33–39, 2022.

[9] H. Tan, "A new approach to green development of university campuses under the goal of carbon neutrality," *Energy and Environmental Protection*, vol. 36, no. 5, pp. 1–12, 2022.

[10] J. Lan, "Wooden architecture in the context of 'double carbon' target: A brief description of the gymnasium design of Changzhou Wujin District Yancheng Junior High School," *Architecture and Culture*, vol. 10, pp. 2–9, 2022.

[11] H. Zhan, "The prospect of wood and bamboo construction in China," *Construction Science and Technology*, vol. 14, pp. 94–96, 2022.

[12] M. Chen, "Research on the effective path of carbon emission reduction of assembled buildings," *Jiangxi Building Materials*, vol. 6, vol. 10–11, pp. 14–17, 2022.