Transactions on Engineering and Technology Research
ISSN: 2960-1797, eISSN: 2960-2246 | Volume 4
ACEGE 2024

Using Revit to Simulate and Improve Building Energy

Yuanji Li [1], Deyuan Zhao [2, *], Guanqi Zhou [3]

[1] School of Architecture and Environment, Sichuan University, Sichuan, China

[2] School of Architecture and Built Environment, Nottingham Ningbo University, Ningbo, China

[3] Qingdao Menual School, Qingdao, China

* Corresponding Author Email: ssydz2@nottingham.edu.cn

Abstract. Nowadays, the global attention to green buildings continues to increase, countries and regions have formulated the corresponding green building energy consumption standards and certification system, to evaluate and certify the energy-saving performance of buildings, in order to promote the development of green buildings. Green building projects continue to emerge everywhere, and green building technologies and materials are constantly innovating and developing. At present, many energy-saving technologies and strategies have been found: through the use of high-performance thermal insulation materials, thermal insulation materials, etc., to improve the thermal insulation performance of building structures, reduce the energy consumption of winter heating and summer cooling; Reasonable design of building heating, ventilation, air conditioning system, using efficient equipment and intelligent control system to improve energy efficiency; Make full use of natural lighting and natural ventilation, reduce the use time and intensity of artificial lighting and mechanical ventilation, and improve the natural lighting and ventilation effect of buildings. In the long run, energy-saving green buildings can reduce the operating costs of buildings through energy-saving measures, reduce greenhouse gas emissions and pollutant emissions generated in the process of energy consumption, and help reduce the energy consumption and environmental pollution of the construction industry, which is of great significance for mitigating climate change and improving environmental quality.

Keywords: Green Building; Energy; Environmental Protection; Sustainability; Revit.

1. Introduction

With the increasing emphasis on environmental protection and sustainable development in the world, green buildings have been widely concerned by the international community as an important way to reduce energy consumption and environmental pollution in the construction field. As an important means to study and realize green building, green building model has naturally become an international hot spot. Many countries and regions have introduced relevant policies and standards to encourage and regulate the development of green buildings, such as LEED certification in the United States and three-star green building standards in China. The implementation of these policies and standards has promoted the in-depth study and application of green building models. Building energy consumption and resource consumption can be significantly reduced by studying green building model, optimizing building design and improving energy efficiency [1].

This is of great significance for alleviating the global energy crisis and protecting natural resources. At the same time, green buildings can also reduce carbon emissions and other pollutant emissions in the operation process, which has a positive role in improving urban environmental quality. In addition, the improvement of indoor environmental quality, such as improving the ventilation effect and enhancing natural lighting, can provide residents with a healthier and more comfortable living environment, which helps to improve the quality of life and happiness of residents [2]. As for the industrial chain, the research and application of green building models have promoted the development of green building materials, energy-saving technology and other related industries. The development of these industries not only creates more job opportunities, but also promotes sustainable economic development [3].

At present, China has adopted a new building mode, which is prefabricated building. The advantages of this building model are very obvious. Compared with the past, this type of structure requires less human resources and has less impact on the environment, so it can achieve carbon reduction [4]. Chinese researchers are also working on broader emissions-reduction targets. As an economically developed region in China, Hong Kong has done relevant research on emission reduction. The study, conducted in Hong Kong, explored whether the existing typical annual generation method was applicable to simulating energy consumption for natural lighting. Similar to this study [5].

2. Methodology

Among the structural analysis software, Revit has obvious advantages, loads, load combinations and boundary conditions can be easily added, and time and effort can be saved to the greatest extent in the modeling process. When modeling, it is very important to understand the physical concept, which is why modeling in Revit can have a good understanding of the physical aspect of the building structure. Software can provide users with physical buildings, and automatically model the physical model in Revit's background, and then analyze the model is handled by the structural analysis software. The user can clearly understand the internal structure of the building, not just the exterior [6].

Take for example the practical application in Brazil. The study is to model and parameterize a wall with openings and an overall model. The relevant technicians first collected the specifications and characteristics and data of the structural wall used in Brazil, and drew technical drawings, which were made with AutoCAD. This is done to identify the parameters used in Revit for modeling. Finally, the parameterization process begins using Revit functions to model concrete walls and insert the necessary rebar using the "Rebar" tool that the software provides. From these models are produced technical drawings, such as plans and sections, which show that the sections are composed of concrete and steel. Automatic quantitative data were also obtained [7]. These are sufficient to show the strong compatibility of this software, and the performance is designed for professionals. This project will use this software to conduct basic data analysis and modeling, and use reference data for further analysis.

The office building model is built by the Revit software which is a powerful tool for people easily obtaining simulation data and relevant useful information. The office building consists of two floors of 4 meters each, moreover the center is an atrium that runs through two floors for better ventilation and lighting seen in the Figure1.

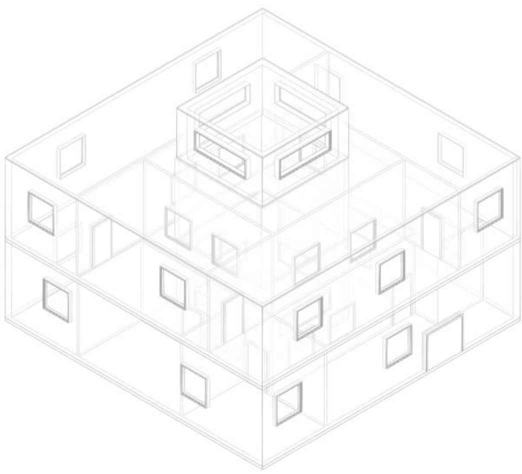

Figure 1. Office Building Model

The basic building information and input data such as schedule, HVAC system, and construction materials are all listed in the below table (Table 1). According to above input data, the office building model is applied to different areas in China for a whole year to explore the influence of building energy consumption in diverse climate.

Table 1. Basic information of office building model

Basic information	Value
Height	10.5m
Length	15m
Width	15m
Total area	$392.81m^2$
Room type	Office
Schedule	Monday-Friday
HVAC system	Central air-conditioning Boiler efficiency: 84.5% Chiller COP: 5.96
Ventilation rate	8L/person/s
External wall material	Lightweight construction - typical mild climate insulation
Internal wall material	Lightweight construction - no insulation
Roof material	Typical insulation - light roofing
Floor material	Heavy construction - no insulation
Window material	Double clear - low radiation cold climate, high solar heat gain coefficient

3. Simulation of atrium building in Beijing,Chongqing, and Ha Erbin

Firstly, Beijing, Chinese capital city, was selected to the location of the office building model as the base case. Beijing is located in the north of the north China Plain to the west and the north of the Shandong plain to the south. The urban heat island effect is an important part of urban climate characteristics, and urbanization also affects meteorological factors such as urban precipitation, humidity, and evaporation. Beijing, as the capital of China, has a higher degree of natural development and greater impact, but it was not taken into consideration in this study [8]. The climate type of Beijing was continental monsoon climate which was very common in China. The monthly average temperature was shown in below table 2. It could be found that the winter is from December to February and summer is from June to August. The year average temperature was relative low.

Table 2. Beijing Average Temperature (1991-2020)

Month	Min (℃)	Max (℃)	Mean (℃)
January	-8.9	2.4	-3.3
February	-6	6.2	0.1
March	0.2	13.1	6.7
April	7.6	21	14.3
May	13.6	27.3	20.4
June	19	30.8	24.9
July	22	31.8	26.9
August	20.8	30.9	25.8
September	14.9	26.6	20.8
October	7	19.4	13.2
November	-1.2	10.2	4.5
December	-7	3.8	-1.6
Year	6.9	18.7	12.75

The office building energy consumption in Beijing was simulated at first. Furtherly, these data would be used to compare with the results of the building model in other places. For instance Chongqing, a hotter city in China, was used to run the office building simulation to compare the energy consumption for different climate. The climate of Chongqing was Subtropical monsoon humid climate. The temperature of Chongqing city was higher than that of Beijing city, hence the cooling load would be increased. The total energy consumption results in Chongqing could be found in below table. At last, the office simulation building is applied to Haerbin city, which was the Medium-temperate continental monsoon climate. The monthly average temperature was quite lower than Beijing, so that the heat load would be much higher. All the energy consumption data in these areas were shown in below Table 3.

Table 3. Office Building Energy Consumption in Beijing

	Beijing	**Chongqing**	**Ha Erbin**
Energy type	Consumption value	Consumption value	Consumption value
Total site energy	556 GJ	431.23 GJ↓	752.46 GJ↑
Total site energy per building area	1415.55 MJ/m²	1097.81 MJ/m²↓	1915.59 MJ/m²↑
Total source energy	1514.92 GJ	957.54 GJ↓	2337.26 GJ↑
Total source energy per building area	3856.64 MJ/m²	2437.67 MJ/m²↓	5950.13 MJ/m²↑
Total heating energy	258.37 GJ	91.96 GJ↓	498.82 GJ↑
Total cooling energy	171.16 GJ	212.76 GJ↑	127.14 GJ↓
Total lighting energy	55 GJ	55 GJ	55 GJ
Total equipment energy	71.5 GJ	71.5 GJ	71.5 GJ
People sensible instant heat	1025.75 W	1025.75 W	1025.75 W
People sensible delayed heat	337.22 W	337.31 W ↑	336.94 W↓
Zone relative humidity	46.76%	46.14%↓	45.52%↓
People latent heat	1172.28 W	1172.28 W	1172.28 W
Lighting sensible heat	4228.15 W	4228.15 W	4228.15 W
Equipment sensible heat	5496.6 W	5496.6 W	5496.6 W
Time of peaking cooling load	7/21	8/21↑	6/21↓
Time of peaking heating load	1/21	1/21	1/21

4. Discussion

According to above energy consumption data of office building in three cities, there are several differences of the results in three types of climate. Therefore, this office model can be used to analyze the suitable constructions in each area.

The office building model with an atrium is most suitable in hot areas where the average temperature is much higher like Chongqing city, due to the lowest site energy consumption (431.23 GJ) and source energy consumption (957.54 GJ) shown in table3. This results show the significance of an atrium for ventilation in tropical areas helping to expel hot air upward. Besides, the energy consumption in Haerbin city is the highest (752.46 GJ), over 35% than that of Beijing city. Thus, it can be found that this type of office building can be more energy saving in relatively hot city, instead for some cold area, the site energy consumption and source consumption are much higher.

It can be found that in hot areas, Chongqing city, the demand of cooling energy increased compared with Beijing city; similarly, in cold region, the demand for heating energy also raised. Whereas, it should be known that the increase of heating energy is more than that of cooling energy. For instance, in Chongqing city the cooling energy increased for 41.6 GJ, approximately higher 24% than the base case. By contrast, the heating energy in Haerbin city increased about 240 GJ, nearly enhanced 93% heating energy consumption than in Beijing city. This phenomenon showed that this type of office building would cause more heat loss in the cold areas, however decrease heat gain in some hot areas. Due to the type of this building does not change, the lighting and equipment energy are stable on

4228.15W and 5496.6W. In addition, the people sensible delayed heat changed slightly with the decrease of relative humidity. Other results like the appearance of peak cooling load were different showing the different type of weather and climates.

5. Improvement Of Building Model Materials

If the construction industry wants sustainable development, then the use of green building materials is very necessary, the efficient application of green building materials to civil engineering construction is an important way to achieve the healthy development of the construction industry, but also an important measure consistent with the direction of sustainable development in China [9-10].

Base on above energy consumption analysis for the office building model in three regions, there were some measurements to minimize the energy consumption. According to different characteristic of these climates, the construction materials were adjusted to prevent the heat loss in Haerbin and Beijing city and heat gain in Chongqing city. The below results would proof the impact on construction materials to different region.

For the Beijing area, the climate was relatively cold, hence the insulation of the building would be improved. Whereas, in Chongqing city, the average temperature was quite high, hence the construction materials were selected for the reflection of solar radiation. Similarly in Beijing city, the cold region need more insulation materials to prevent heat loss and should maximize the heat gain by daylight. All the improved construction materials were shown below table 4.

Table 4. Changing Construction Materials in Beijing, Chongqing, and Ha Erbin

City	Construction Component	Original Material	Improved Material
Beijing	Floor	Heavy construction - no insulation	Heavy construction - cold climate floor insulation
	Window	Double clear - low radiation cold climate, high solar heat gain coefficient	High performance, low-E, high visible light transmittance, Low solar heat gain coefficient
Chongqing	External wall material	Lightweight construction - typical mild climate insulation	Heavy construction - high insulation
	Internal wall material	Lightweight construction - no insulation	Heavy construction - no insulation
	Window	Double clear - low radiation cold climate, high solar heat gain coefficient	Four layers clear - Low-E Hot climate or cold climate
Ha Erbin	External wall material	Lightweight construction - typical mild climate insulation	Lightweight construction - typical cold climate insulation
	Floor material	Heavy construction - no insulation	Heavy construction - cold climate floor insulation

After changing the construction materials, the energy consumption results of the office building model in these areas significantly reduced. The detailed comparison are listed below (Table 5).

Table 5. Energy Consumption Improvement after Changing Building Materials

	Beijing	Chongqing	Ha Erbin
Energy type	Consumption value	Consumption value	Consumption value
Total site energy	547.37 GJ↓	399.67 GJ↓	686.56 GJ↓
Total site energy per building area	1393.47 MJ/m^2↓	1017.47 MJ/m^2↓	1747.82 MJ/m^2↓
Total source energy	1491.86 GJ↓	883.6 GJ↓	2154.51 GJ↓
Total source energy per building area	3797.92 MJ/m^2↓	2249.44 MJ/m^2↓	5484.89 MJ/m^2↓
Total heating energy	252.93 GJ↓	76.08 GJ↓	454.57 GJ↓
Total cooling energy	167.93 GJ↓	197.09 GJ↓	105.48 GJ↓
Total lighting energy	55 GJ	55 GJ	55 GJ
Total equipment energy	71.5 GJ	71.5 GJ	71.5 GJ
People sensible instant heat	1025.75 W	1025.75 W	1025.75 W
People sensible delayed heat	335.32 W	337.31 W	336.94 W
Zone relative humidity	46.75%	46.14%	45.52%
People latent heat	1172.28 W	1172.28 W	1172.28 W
Lighting sensible heat	4228.15 W	4228.15 W	4228.15 W
Equipment sensible heat	5496.6 W	5496.6 W	5496.6 W
Time of peaking cooling load	7/21	8/21	6/21
Time of peaking heating load	1/21	1/21	1/21

Observing the above tables, the energy consumption in each area has decreased a lot, which proofs changing the construction materials played a vital role in building performance. Although, improved Beijing model just decreased 1.5% compared with original site energy, it still minimize about 8.63GJ. Moreover, in Chongqing city, the enhanced materials help decreasing 31.56GJ energy consumption about 7.3%. In addition, the most efficient improvement was the model in Haerbin, which decreased 66GJ (8.7%) site energy and 182.75 GJ (8%) source energy.

6. Conclusion

In general, the problems of environment and energy are becoming more and more serious in the world. Therefore, to save more energy sources, this report used the Revit software to build a office building model and run the simulation to analyze the energy consumption in three places with different climates. According to above results, this type of office construction model was most suitable to the hot regions like Chongqing city. Therefore, in some hot places, it was recommended that the atrium office building would be applied for exhausting hot air efficiently. Whereas, in extreme cold climate like Ha Erbin, the site energy consumption was relatively high, more than 35% that of office model in Chongqing. Thus to solve these problems, the construction materials were changed to adjust local climates and new simulations run to test the new model performance.

Based on different climates, the materials of construction components such as wall, window, and floor changed to enhance building performance. In cold cities like Ha Erbin, the heavy construction materials with cold climate insulation would be installed to reduce heat loss and save the total site energy. In some hot climate areas, such as Chongqing. both external and internal walls were changed to heavy materials. Besides the window also changed to more layers for preventing sunlight energy coming in the building. The above table 5 proofed that suitable construction materials would lead to a significant reduction in total site energy consumption and total source energy consumption. In addition, it was found that the air relative humidity could influence the people delayed heat. It is hoped that this report would help people to choose suitable construction materials for building office building in different areas. The green building technology and software simulation could be more applied in the building construction process to save more energy.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

[1] Z. Y. Yang, H. Shan, X. Tian, Y. Da, J. Yi, Method and application of global building operation energy use and carbon emissions comparison in the context of carbon neutralitym, Adv. Clim. Chang Res. 19 (6) (2023) 749.

[2] S. Guo, D. Yan, S. Hu, Y. Zhang. Modelling building energy consumption in China under different future scenarios, Energy, 214 (2021) 119063.

[3] M. H. Jahangir, S. G. Motlagh, Building energy and exergy analysis of the light-weight roofs compared with the traditional ones in different climates, Energy Rep. 10 (2023) 1069-1090.

[4] J. Sun, Z. Li, C. Li, X. Feng, Effect of typical meteorological year selection on integrated daylight modeling and building energy simulation, LMGC, 1 (1) (2023) 14.

[5] A. Z. Sampaio, P. Sequeira, A. M. Gomes, A. Sanchez-Lite, BIM methodology in structural design: A practical case of collaboration, coordination, and integration, Buildings, 13 (1) (2023) 31.

[6] B. Habte, E. Guyo, Application of BIM for structural engineering: a case study using Revit and customary structural analysis and design software, J. Inf. Technol. Constr., 26 (2021) 1009-1022.

[7] F. Hu, X. M. Liu, L. Li, Y. Wang, Summer urban climate trends and environmental effect in the Beijing area, Chinese J. Geo., 49 (3) (2026) 617-626.

[8] B. Zhou, Z. Liao, S. Chen, H. Jia, J. Zhu, X. Fei, Net primary productivity of forest ecosystems in the southwest karst region from the perspective of carbon neutralization, Forests, 13 (9) (2022) 1367.

[9] X. Xu, X. Li, Application analysis of green building materials in civil engineering construction. Sci, Technol. Adv. Mat. 2 (1) (2020) 12-12.

[10] D. M. Nguyen, J. Zhang, M. Rahim, D. Hoang, G. Promis, M. E. Ganaoui, A. D. Tran-Le, A review of microstructural characterization and liquid transport in porous materials through image processing techniques, Transport Porous. Med. 4 (2024) 1-22.