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Solar Energy Consumption Simulation Study based on BIM

Wei Zhou

Institute Of Civil And Building Engineering, Wuhan Huaxia University of Technology, Wuhan 430223, China
weizhou3718@163.com

This paper analyzes the energy consumption simulation based on BIM by researching a lot of documents. BIM is used to construct various building models to conduct the comparative analysis. The horizontal sunshade of the building is 487 mm. When the heat transfer coefficient of outside window materials reduces, the annual energy consumption of per square meter drops from 237.78 k Wh/m^2 to 206.89 k Wh/m^2. BIM is used to assist the architectural design, which can directly analyze and design the energy consumption with strong practicability

1. Introduction

According to forecasts from domestic and foreign relevant departments, the global energy consumption will rise sharply from 9.906 billion tons to 9.906 billion tons of oil equivalent between 2001 and 2025, with an increase of 59.04%. On the basis of forecasts from the European Union and other energy agencies, the peak of global energy consumption will occur between 2018 and 2035. In the long run, global fossil fuels will be exhausted. Some foreign experts point out that global energy will be largely mined this century. The global energy statistics 2015 shows that the world's proven reserves of oil are available for more than 36 years, while natural gas and coals are available for 62 and 149 years, respectively. An analysis of the international energy agency in 2012 concluded that the global energy demand would grow by 54% in 2025. However, there will still be "sufficient" energy to meet the global demand. In addition, the transport sector will consume a large amount of resources. From now to 2025, the share will rise from 39% to 51%, resulting in carbon dioxide emissions increase dramatically. Carbon dioxide and sulfur dioxide will become the focus of energy conservation and emissions reduction. Foreign related meetings show that the Middle East will increase investments in oil resources, actively develop and utilize resources such as oil sands, and pay attention to the development of clean energy. By 2025, renewable energy, as an indispensable energy, can further control the greenhouse effect. Based on this, it is of great practical significance to study the solar energy consumption simulation based on BIM.

2. Overview

BIM technology has been applied in the construction field in many countries after a series of developments. It has the following advantages. The construction time is saved, which reduces the cost of the building. By optimizing the design, the final quality of the building is guaranteed. It can manage all the information in the building's life cycle. As a high-tech technology in the construction industry, BIM will be a new revolution in the construction industry, and the most important point of architecture is its energy efficiency. Therefore, the energy consumption simulation of solar buildings based on BIM technology was studied. The concept of BIM was proposed by Dr. Chuck Eastman. The building information model integrates all geometric model information, functional requirements, and component performance. All the information of a building project's entire life cycle is integrated into a single building model. In addition, it also includes process information such as construction progress, construction process, and maintenance management.

The core of BIM is information. BIM has complete building information. It can extract information and then analyze, edit, and calculate information. Therefore, BIM can be said to be the process of information processing or the carrier of information storage. BIM models have "uniqueness" and applied "diversity." The BIM application model is the sharing and collaborative management of information models. BIM technology is

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3D CAD technology (Abanda and Byers, 2016). It can realize the virtualization of building information and express the building information in a parametric form. The common software categories in BIM include model checking software, visual software, structural analysis software, mechanical and electrical analysis software, sustainable analysis software, geometric modeling software with BIM interface, BIM program design software, publishing and auditing software, operation management software, cost management software, model comprehensive collision inspection and deepening design software. The advantages of BIM in architectural design are as follows. The virtual building information model is built and visual editing is performed. Drawing documents are automatically generated. It can achieve automatic change and management and has advanced analysis capabilities.

Shanghai Center is a high-rise construction project that uses BIM throughout the design process (Ghaffarian Hoseini et al., 2017). It embodies the powerful modeling and collaborative design advantages of Revit software. Shanghai Center applies BIM technology for architectural design, construction management and later operation and maintenance management, so as to maximize the social and economic benefits of the entire life cycle of the building. In order to realize the green and energy-saving goals of the building, the National Grid Pavilion of the World Expo has introduced BIM technology during the design process. The architectural design is also based on the Revit series of design software (Guo and Wei, 2016). Various professional collaborative designs are implemented. It can well coordinate the conflicts between various professions and optimize the design of buildings. The California Academy of Sciences also used BIM technology to create the architectural model of the project during the design process. Based on the BIM model, the performance of the building was analyzed and simulated.

In the 1970s, an energy crisis broke out in the world, and people have attached great importance to building energy conservation. With the emergence of BIM technology, more and more researches on BIM have been conducted. The development of building energy conservation in China began in the 1980s. The first building energy-saving industry regulation "Civil Building Energy-saving Design Standard" was promulgated on August 1, 1986. In the 1990s, the promotion of building energy conservation was increased on the basis of the original. A large number of policies and regulations on building energy efficiency were studied and formulated, such as the formulation and implementation of energy efficiency standards and regulations, and the development and promotion of energy conservation technologies (Kim et al., 2016). In December 1995, the second building energy-saving design standard was promulgated. The energy-saving standard was raised from 30% for the first time to 50%. The "Energy Conservation Law of the People's Republic of China" was promulgated on January 1, 1998, which greatly guides energy conservation throughout the country. It is also the legislative basis for building energy efficiency. In 2006, Hong Kong began to study the application of BIM technology in the construction process and applied it to various types of real estate development. In 2008, mature BIM technology can already be used to build 3D building information models for architecture and structural design. In 2009, the Hong Kong BIM Institute was established. Since 2010, China has begun to promote the practical application of BIM from the government level. It is hoped that a new situation will emerge in the traditional construction industry.

Based on BIM technology, the management and maintenance of existing school buildings are studied (Rasiulis et al., 2015). The research direction is mainly in the field of renovation and reuse of existing buildings. Energy efficiency and structural improvements are being researched. BIM technology is used to control the latest information on engineering and quality. The project uses BIM technology to define a new work concept from the beginning of software operation. The optimization of the process will generate a complete architectural modelling, including buildings, structures, facilities, and deterioration. Existing buildings are better managed and maintained. The rapidly changing climate and global energy crisis are concerned. Combined with BIM technology, the concept of green building information model was proposed (Shoubi et al., 2015). With the aid of BIM tools, building performance is analysed to obtain the best design solutions to optimize the local climatic conditions. Through BIM, the influence of window size, position and orientation on building energy consumption was studied (Wong and Zhou, 2015). In terms of improving the energy efficiency of buildings, windows largely influence the energy load. Based on BIM technology, the influence of window size, position and direction on the energy load is analyzed. The results of the BIM study showed that when the window is at the mid height of all heights, the load required by the building is the lowest, while the positioning of the east window has the greatest impact on the total energy load (Yamamura et al., 2017).

In summary, energy is the support and driving force for the economic development of a country. It not only concerns the social stability and normal operation, national security, sustainable development of the ecological environment, but also involves the survival and continuation of future generations. With the advancement of science and technology, the social and economic development of various countries in the world is rapidly developing, and the demand for energy is also increasing. The surge in energy demand has caused numerous environmental problems. In today's increasingly prominent energy and environmental issues, there is a need for new energy sources. Solar energy is slowly developing in this environment. The development of solar

energy has led to the development of solar buildings. Therefore, the BIM (Building Information Model) technology has also been widely developed.

3. Research methods

Through reading and analyzing domestic and foreign related theoretical works, periodicals, dissertations and documents on the Internet of BIM, the information and research methods are obtained to make preparation for the in-depth study.

With the development of social economy, globalization, urbanization and sustainable development become three main trends of modern construction development. The application and development of BIM is broader and faster, especially in the early stages of building energy efficiency design. This paper provides advanced technology and ideas through the case analysis, and concludes how BIM energy consumption analysis assist architects to choose the energy saving solution and to optimize the design.

BIM uses the digital technology to build a virtual building in the computer, which provides a single, complete and logical building block. Real information is formed through digital simulation of buildings that helps architects to abandon traditional two-dimensional drawings. There is no need for architects to use traditional two-dimensional construction drawings to express a three-dimensional complex shape, which greatly expands architects' exploration for architectural forms. BIM is a direct embodiment of digital simulation technology in actual engineering projects to solve the software description problems and provide necessary information for designers and other engineering staff, dealing with all kinds of information properly and paving the way for collective work. Building information model supports integrated design and management of construction projects, which greatly improves work efficiency and reduces risks. According to the ancient Chinese philosophy, the law of BIM movement can be found. There is an old saying "Tao contains Yin and Yang". The composition of Yin and Yang is a dynamic state of cycles, which is called Tao. Figure 1 shows the "BIM Heluo Figure " to explain basic concepts of BIM through Yin and Yang.

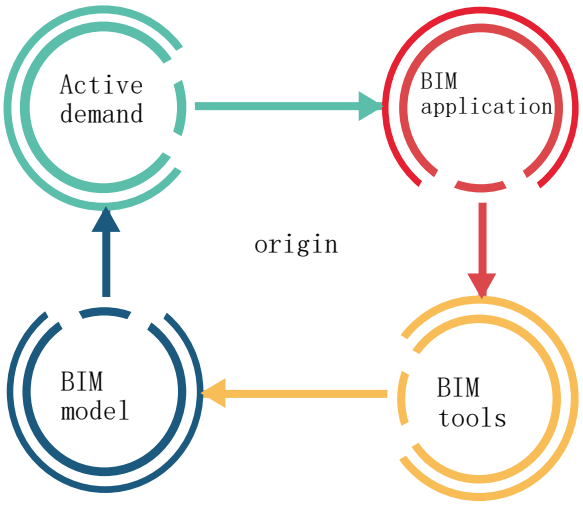

Figure 1: BIM Heluo Figure

4. Results and Discussions

In the early stage of scene investigation, on the basis of data collection, building energy efficiency design is proposed to solve the following key problems to adapt to the climate, topography and landforms: 1. To determine the energy-saving design strategy based on the analysis of climate; 2. To rationally design the building orientations, which not only meet the needs of functional layout, but also achieve the purpose of building energy conservation; 3. To define functional zones and reasonable layouts to meet the needs of special building functions and avoid auxiliary functions such as passages and toilets in favorable orientations; 4. To fully utilize natural lighting through designing reasonable building volumes and space forms to strengthen the natural ventilation and reasonable shading forms; 5. To choose reasonable building maintenance structure materials, which are both economical and energy-saving.

With a humid typical subtropical monsoon climate, Chongqing has four distinct seasons with an annual average temperature of 18 ℃ or so. The average temperature of Chongqing in winter is around 6 to 8 ℃, while summer is hot and humid. Chongqing is known as "a mountain city" for its hills and mountains.

Chongqing has hot summer as well as humid and cold winter with a large annual average precipitation. The temperature difference between morning and evening is not great with little sunshine time. The rainy weather will appear during the transition period of spring and summer. Chongqing also has unique climate characteristics: 1. The annual average temperature is higher at 18 ℃ or so. Because of its topography, the temperature is uneven in this city that is the west is higher than the east. In the Yangtze River, Jialing River and other areas with lower elevation, the closed topography makes the airflow unsmooth with a higher temperature. In the southern and eastern mountains with a high altitude, the air flows relatively smoothly and the temperature is lower. Chongqing's summer is called a "stove" because of its hot weather. Figure2 shows that the average temperature is around 28 ℃, even more than 40 ℃ of extreme high temperature weather from the 24th to 32nd week.

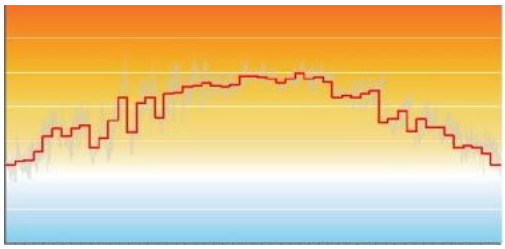

Figure 2: Average Temperature in Chongqing

Chongqing is located at the intersection of two rivers (Yangtze River and Jialing River), where the water vapor is abundant and the air is relatively humid. Chongqing has been known as a "foggy city" with little solar radiation, because the annual average foggy day is up to 68 days, especially from the end of autumn to the early spring. Figure 3 is the annual solar radiation in Chongqing.

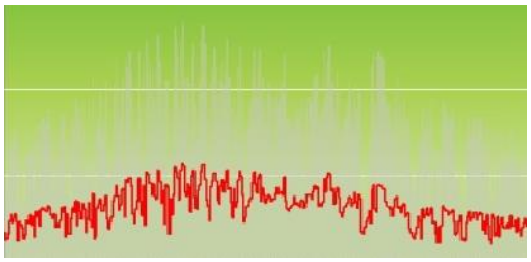

Figure 3: Annual Solar Radiation in Chongqing

The wind speed in Chongqing is small, belonging to the smallest wind speed areas. It is ringed by mountains on three sides that lead to the regional airflow is not smooth. There is no wind in Chongqing for 36% to 50% time and the annual average wind speed is small as shown in Figure 4.

Figure 4: Annual Wind Speed Chart

After ordering basic functions of buildings, it is necessary to determine the basic form of buildings, combining with the building orientation selection. The lighting and radiation of buildings are better, but the ventilation is not great. According to the analysis of Chongqing's humid climate, although the wind speed is small, natural ventilation is particularly important for the building energy conservation. Figure 5 illustrates the natural

ventilation in Chongqing is important to improve the indoor comfort. Therefore, the architectural form design should focus on the ventilation.

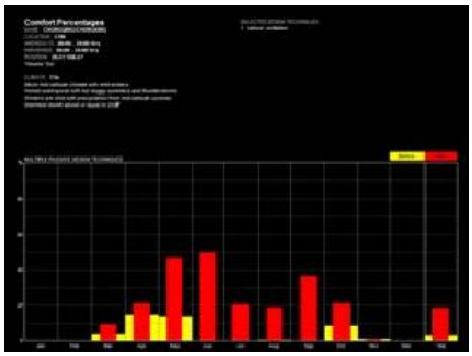

Figure 5: Natural Ventilation

The formula is $S = (A + 4)8 * (B + 4) = S + 2L + 16$. The main body is a two-story building. The north entrance is shaded by the south in summer, as shown in Figure 6. Moreover, the building is in a C layout from north to south. There are verandahs above the third floor in the north for shading and ventilation. Therefore, the focus of shading in summer is in the south.

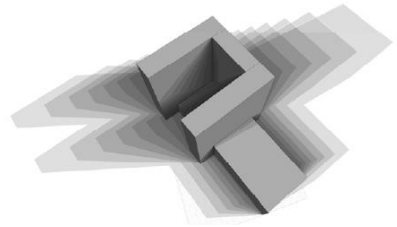

Figure 6: Scope of Shadow

BIM is used to guide shading design. Based on the BIM analysis, the horizontal sunshade of the building is 487 mm. The shape of building is optimized with the combination of shading design, as shown in Figure 7.

Figure 7 : Architectural Shading

For the design of outer wall materials in the court rooms expansion project of the Second Intermediate People's Court, sintered shale hollow (porous) bricks as filler walls, aerated concrete block, and composite wallboard with thermal insulating layers are all good thermal insulating materials, in addition to the structural reinforced concrete. The external thermal insulating system adopts inorganic insulating mortar, which has a small heat transfer coefficient, to meet the requirements of building energy saving design standards.
Comparative analysis of results: after improving building walls' insulating properties, the energy consumption of per square meter reduces significantly from 252.29 k Wh/m^2 to 237.78 k Wh/m^2. Therefore, the energy saving effect of aerated concrete block is more obvious. In the design of the court, aerated concrete block is selected as the exterior wall maintenance structure. With the help of BIM, it can be very intuitive to provide

reference for us to choose more economic and reasonable wall materials, according to the costs, operational life, energy saving, and etc.

In the design of building energy efficiency, the selection of window materials is also important. The following ways can reduce the heat transfer coefficient of doors and windows in order to meet the provisions of building energy efficiency design standards: 1) the plastic thermal insulted aluminum alloy window frame is selected; 2) the glass materials with low heat transfer coefficient is used; 3) the doors and windows with good sealing performance are adopted. The energy consumption of two kinds of glass materials is analyzed under the BIM energy consumption analysis.

Comparative analysis of results: when the heat transfer coefficient of outside window materials reduces, the energy consumption of per square meter decreases greatly from 237.78 k Wh/m^2 to 206.89 k Wh/m^2. There are more than 10,000 square meters building areas with 300,000 k Wh energy saving each year. Therefore, in the design of the court, the standard double-layer colorless gas-filled Low-E glass is selected as the outer window material. With the help of BIM, it can be very intuitive to provide reference for us to select external window materials, achieving a balance in energy saving and economy.

The essence of BIM is information, which is throughout the entire life cycle of projects. The required information is of great significance for the project construction and later operational management.

5. Conclusion

This paper analyzes the solar energy consumption simulation based on BIM. The result shows that the horizontal sunshade of the building is 487 mm. When the heat transfer coefficient of outside window materials reduces, the annual energy consumption of per square meter drops from 237.78 k Wh/m^2 to 206.89 k Wh/m^2.

It is difficult to choose analysis tools quickly with the traditional analysis method, which is mainly due to the complexity of the project. At the same time, because of the influence of climate, seasons and other factors, the gap between some models and actual data is large, which cannot ensure the accuracy of data analysis. Secondly, there are some deficiencies in the only analysis software PKPM, which cannot take the economic efficiency into consideration in the analysis process. If the design needs to be modified, it is difficult to make up for the deviation. BIM can carry out the analysis and design of energy consumption directly with convenient modeling and change modes. At the same time, the building model can be directly output into drawings with stronger practicability.

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