Application of BIM energy conservation technology in conceptual design

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Abstract. Energy is a necessity of social and economic development, and buildings account for one third of the world’s total energy consumption. To reduce the energy consumption of buildings is important in the energy conservation initiatives. In construction projects, energy-saving design can be implemented only when the construction diagrams are prepared, which leads to contradictions between the construction plan and the goal of saving energy. Therefore, it is necessary to emphasize energy conservation in the conceptual design of buildings. The BIM technology can provide a reliable basis for architects in energy conservation design. With BIM models introduced to energy-saving design, we can identify, convert and analyze the building data in the models to obtain architectural energy-saving analysis results more efficiently. With BIM technology, we can involve energy conservation in the conceptual design stage to provide a basis for energy conservation.

1. Introduction

1.1. Research background
With economic growth, people are enjoying a higher living standard and also a higher demand for comfort of buildings, with higher requirements for energy conservation. The energy consumption of the construction industry in China has increased year by year from 2000 to 2018, as Figure 1 shows.

Without elaborate analysis in initial design of buildings, the buildings may suffer from problems like poor lighting, high energy consumption and disagreement with the local climate. In the past, due to the complicated data exchange between the conceptual design and energy consumption simulation of buildings, interactions between initial design and construction are not sufficient, which hinders energy conservation analysis in initial design and latter utilization of buildings[1]. In early design, the construction elements like lighting, ventilation and energy consumption are not analyzed, let alone visualization of data in these regards.

Figure 1. Total energy consumption of China’s construction industry from 2000 to 2018
The introduction of BIM technology makes up for the downsides of the traditional design tools. The strengths of BIM technology in informatization and visualization provide rich data for architects to refer to in design. With BIM, architects can make timely adjustments and improve the performance of the building in all aspects. It helps improve the utilization of resources, reduces investments, and facilitates sustainable architectural design.

1.2. Introduction to BIM
Building information modelling (BIM) is a collaborative working process using digital models to support virtual design and construction, which can streamline project delivery workflow and improve business performances and productivity throughout the total life cycle of building assets. In principle, BIM can be defined as the process of creating and using digital models for design, construction, and/or operations of building or infrastructure projects. A BIM model is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle. In recent years, BIM adoption has grown significantly in many countries and cities around the world. BIM is considered a major driver for the digital transformation and innovation of the construction sector; also, it has good potential to enhance sustainable construction and environmental sustainability[2].

In recent years, there are many researches and literatures on the role of BIM in sustainable architecture, and the related publications on this topic are growing exponentially[3].

BIM realizes visualization, coordination, simulation and capacity to produce graphs. All these features run through the whole architectural design, which allow communication among different parties involved in construction, facilitate coordinated design and improve decision-making[4].

The BIM technology helps performance analysis of buildings in the conceptual design stage, such as the interior and exterior lighting environment, the interior and exterior wind environment, energy conservation analysis, and evacuation condition analysis. It also enables comparison of schemes and design optimization.

1.3. Research purpose and meaning
Only with the idea of sustainable development in mind can the architects design sustainable green buildings. Subjective judgment and the rule of thumb are not enough to process the complicated construction information. With computer technology, architects can compute and simulate the complicated data to analyze the energy consumption of buildings and realize energy-saving construction design. The BIM technology that integrates large volumes of construction data provide an even better solution. By BIM modelling, architects can analyze energy consumption of buildings in their conceptual design conveniently, and the analysis results can help architects to make timely adjustments and realize energy-saving design of buildings.

This study aims to fill the vacuum of research on the application of BIM energy-saving technology in architectural conceptual design to provide a basis for sustainable design of the whole-life cycle of buildings, which precedes energy conservation design and reduces repetitive work.

2. Research methods and process
2.1. Introduction to the study case
A semi-detached house in Fujian was taken as the study case. Introducing BIM energy-saving technology to the construction conceptual design helps design and modification of the construction plan. The studied house is three-story building, with the first floor 3.2 m high, and the other two floors 3.0 m high. The architectural style is Chinese. The wall is made of aerated concrete blocks, and the exterior wall is coated by stone paint, as Figure 2 shows.
2.2. Elements of conceptual design and requirements of energy-saving design
Conceptual design involves three stages: task analysis, conception and in-depth analysis, as Figure 3 shows. The analysis determines the orientation, plane, number of windows and stories, height, style and materials of the building.

The orientation, plane, shape, windowing and materials are closely connected to energy-saving design. In the study case, the architect optimizes the design by adjusting the shape, the position and orientation of the windows, which meets the functional and aesthetical functions of the building and reduces the energy consumption of the building.

2.3. Tools for conceptual design
In the conceptual design stage, due to the short design cycle and uncertainties in design, architects do not need to perform overall energy-saving design. As warming and air-conditioning take up 65% of the total energy consumption. The building shape and windowing have large impacts on the warming and air-conditioning of the building. In the conceptual design stage, energy-saving design can be implemented in these regards.

Mainstream energy-saving design include the following three methods:
1) Designing and sketching the drawings in 2D graphic design software, and inputting the drawings into the BIM energy-saving software to rebuild a model for energy conservation design;
2) Designing and modelling 3D BIM software, inputting the data into the BIM energy-saving model to recognize data of the model and perform energy-saving design;
3) Designing and modelling on the BIM platform to perform energy conservation calculation.
The first method is rather complex and does not fit energy-saving design; the second method is more popular and practical; the third is limited to the BIM platform and allows fewer options. Thus, the second method is employed in this study.

The BIM design software adopts Revit2016, and the BIM energy conservation software adopts the BECS2020sp1. In BECS, the BIM model prepared by Revit can be recognized directly.

2.4. Energy design process in the conceptual design stage
1) In the conceptual design stage, the Revit is used to draw the plane graph of the building and prepare the BIM model, as Figure 2 shows.

2) The BIM model prepared by Revit is output in the sxf format and input into the sware energy conservation software;

3) The BIM model is recognized to perform space division, room searching and room arrangement, as Figure 4 shows.

4) Setting of the project is performed. The study case is a residence in Fujian and conforms to the “Design standard for energy efficiency of residential buildings in Fujian” DBJ13-62-2019. As stipulated in the Standards, the space coefficient is $\leq 0.55$; the window-floor area ratio of the bedroom and living room is below 1/6; the windows facing east and west adopt sun-shading measures. Therefore, it is necessary to check whether the space and windowing of the design scheme meets the requirements.

5) Energy conservation checks show that the space coefficient of the building is 0.51, which meets the standards. The area of windows of the south-facing bedroom is small, which fails to meet the requirement that “the window-floor area ratio should be below 1/6”; and no sun-shading measures are taken in the east- and west-facing windows, thus failing to meet the energy conservation standards.

6) Returning to Revit to modify the scheme. The width of the south-facing bedroom window is changed from 1200 mm to 2400 mm to increase the area of windows, as Figure 5 shows.
7) Re-uploading the model into the energy conservation calculation software, and it is found that the window-floor area ratio of the bedroom has met the standards. Moreover, initial energy conservation checks reveal that without thermal protection on the exterior wall, the building already meets the standards for the thermal transfer coefficient of the exterior wall, and there is no need to calculate the thermal protection thickness of the building area.

3. Research result
Based on BIM technology, the architects can adjust the energy conservation design schemes to meet the design requirements and fulfill the feasible plans for energy conservation design. Energy conservation calculation is performed directly on the Swaro energy conservation software to generate the design report and provide a basis for BIM energy conservation design. The energy conservation report is presented in textual and statistical and graphical forms to facilitate the design of architects and property owners, as Table 1 shows.

Through conceptual design, scheme in-depth design and energy conservation design, we explored the practical value of BIM energy conservation technology in construction conceptual design. Energy conservation design has great impacts on the building space, the windowing and exterior appearance of the building. If the energy conservation design is not considered in the conceptual design stage, re-work of the conceptual design may be required.

Table 1. General solar heat gain coefficient

| Towards   | Area (㎡) | Weight coefficient b | Shading coefficient | General solar heat gain coefficient |
|-----------|-----------|----------------------|---------------------|-----------------------------------|
| Southbound | 56.640    | 1.00                 | 0.55                | 0.48                              |
| North     | 24.000    | 0.80                 | 0.55                | 0.48                              |
| Eastward  | 11.100    | 1.00                 | 0.55                | 0.48                              |
| Westward  | 11.100    | 1.25                 | 0.55                | 0.48                              |
| Average shading coefficient of the entire building |           |                      | 0.54                              |
| Comprehensive solar heat gain coefficient of the entire building | |                      | 0.47                              |

External wall thermal engineering $ K=0.83, D=4.62, \rho=0.75$

Inspection basis “Design standard for energy efficiency of residential buildings in Fujian” DBJ 13-62-2019 Article 4.2.5

standard requirement $(S w \leq 0.90 \text{ or } SHGC \leq 0.80)$

Inspection findings Satisfy

4. Conclusions
The core of the BIM technology is that it carries the building model information and provides a statistical basis for calculation and modelling. It has great value for architectural design and promotes the development of the whole construction industry. As the BIM and relevant technologies improve and the requirements for design, construction and maintenance increase, the BIM technology sees wider adoption. In the energy conservation field, BIM helps optimize the design and improve sustainability of the buildings[5]. In the initial design, the spatial correlations, the lighting and ventilation conditions and energy consumption of the buildings can be analyzed to provide technical feedback to the design scheme, help the architects in decision-making and facilitate implementation of the schemes. The BIM energy conservation technology has great application value and potential in conceptual design.

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