Analysis of Designing Green Architecture Based on Building Information Modeling (BIM) Technology

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Abstract. Architecture industry is one of the most important energy consumers and environmental polluters. Ensuring the ecological stability and the environmental sustainability for humankind, developing green architecture is an urgent need. How to design green architecture properly is the key to constructing energy-saving and sustainable architecture. This paper analyzed the designing procedures of green architecture and the problems in the designing process, and explained how to use Building Information Modeling (BIM) technology to deal with the problems, providing references for designing green architecture.

1. Introduction
At present, digitization has become the cutting-edge technology that draws great concern from different industries as the technology develops rapidly. In the context of digitization, the digitized technologies are widely applied in the architecture industry, triggering a reform in the architecture designing. Meanwhile, with the development of architecture industry, the pollution caused by it has attracted people’s attention since the building projects have consumed natural resources and produced a large amount of waste. Architecture industry has become one of the largest energy consumers and the largest CO2 producers. As people’s anxiety about the global warming is increasingly growing, departments of architecture construction have started to reach an agreement about developing green architecture.[1] To ensure the ecological stability and the environmental sustainability for humankind, it is urgent to promote green architecture. Moreover, the key to energy saving and architectural sustainability is designing green architecture in a proper manner.

2. Overview of green architecture and BIM technology

2.1. Green architecture
The new idea of green architecture was put forward by Paola Soleri Italian-American architect. In 1960s, he combined “ecology” with “architecture” to create a new word “Arology” while proposing the famous idea of green architecture. Green architecture conforms to the principle of sustainable development, presents the concept of green balance, and accords with the requirement of ecological development. The idea of green architecture raised by the Green Olympic Building Assessment System of China refers to saving energy, water, land, materials to the maximum, and reducing the harm of gas, liquid, solid waste to the atmosphere, water, ecological circulation and natural
environment to the maximum, with the purpose of creating a healthy people-environment relation and comfortable indoor and outdoor environment which focuses on health and is complemented by comfort. [2]

2.2. BIM technology
Building Information Modeling (BIM) is an emerging technology that is increasingly applied in the architecture industry. By BIM technology, the traditional two-dimension modeling design can be transformed into three-dimension or multi-dimension modeling to make the architectural combination and spatial layout designing more reasonable and clearer.

Generally, BIM can be applied in sustainable practice such as planning, designing, constructing and maintenance of architectural projects and it can control the environmental influence by advanced and professional knowledge. In 2008, Krygiel and Nies, who put forward the idea of “Green BIM” the first time, published books related to the sustainable development of Green BIM. They have explored the influence of BIM on upgrading the designing practice of contributors in architecture industry, and adopted BIM procedures to promote sustainable designing in the building performance simulation (BPS).[3] By BIM technology, optimal energy-saving plans can be obtained from the selection of raw materials to the construction operation and management of architecture, which plays a key role in accelerating the development of green architecture designing.

3. Designing procedures and common problems of green architecture designing
The procedures of green architecture designing from the preliminary designing to finishing a drawing are shown in Figure 1. According to the working time order, we divided the designing procedure into three phases, namely the preliminary phase of conceptual designing, the initial phase of designing and the phase of designing construction drawings.

![Figure 1. Procedures of designing green architecture](image)

In the preliminary phase of conceptual designing, the data should be collected such as the location, geological hydro-logical conditions, size and shape the project site, ecological environment of the site surroundings, existing buildings and transportation, provincial infrastructure, climate, sunlight, wind direction, average temperature and humidity. After analyzing these data, the site is designed. When designing the site, we should remain the original ecological environment as much as possible, reduce the destruction of terrain and vegetation, make good use of existing natural conditions, and follow the terrain to design a basic framework. Drawings should focus on the building layout, general layout, layout of every floor, one to two representative facades and sections. The common issues in the designing process: how to choose the best direction of the building, how to determine the building
shape and facades, how to decide the intervals of buildings, and how to undertake energy consumption simulation.

In the initial phase of designing, the structural, electrical and mechanical professional knowledge should be referenced when it comes to designing the building layout. The plan will be retouched after the drawing in the former phase and this will change the facade modeling. The plan functions and facade modeling will be designed repeatedly to reach the requirements of rational plans, beautiful appearance and environmental protection. In this phase, multiple professional majors such as architecture, structure and Heating, Ventilation and Air Conditioning (HVAC) should be coordinated to optimize the design. The common problems in this phase include how to optimize the architectural designing scheme and how to control the overall budgetary estimate of project construction, etc.

In the phase of designing construction drawings, all professional workers need to improve technical drawings and calculations, collaboratively deepen the design, proofread the drafts with each other, produce drawings and complete comprehensive data analysis of energy consumption. Common problems in the designing process include how to check errors and omissions in the comprehensive layout of pipelines, and how to realize comprehensive data analysis of energy consumption, etc.

4. Analysis of how BIM technology addresses the common problems in the process of green architecture designing

It is inevitable to produce errors only by using human designing mindset as there are many factors taken into account in the designing process of green architecture, including the common factors of architecture designing, the health of users, the function of saving energy, and the principle of sustainable development. Moreover, it is also because the spatial relationship of the architecture project is complex, which means the space of a building is related to many architectural components and facilities. Meanwhile, there are other effects which need to be considered. For these reasons, the only use of human designing mindset can produce errors. For example, if using conventional simulation to analyze the performance of green architecture, we must input the data to rebuild a model to analyze once again when using different software of performance analysis; and besides, when the designing scheme is changed, we must input the data and rebuild a model to check again, which can waste numerous human and material resources. Fortunately, BIM technology can address these problems. In the designing process, the model built by BIM technology has stored a large amount of designing information. The technology can make several software be compatible with each other to share the data and we do not need to rebuild a model when changing the designing data in the performance simulation. These advantages reduce a lot of time to operate repeatedly. Moreover, BIM technology can present the complex relationship of different components by using a three-dimension model and combine various data of the architecture, making it clear for the designer to control every link of the construction, compare and adjust different effects in the process. In this case, the errors in the designing will be reduced and repairing work can be avoided, which greatly improves the quality and efficiency of architecture designing.

4.1. Application of BIM technology in the preliminary phase of conceptual designing

The first thing to consider is architectural layout. After the macro scope of the building site is determined, BIM technology can be applied to analyzing the relationship between the building and its surroundings, considering the soil structure of the site, and finally choosing the best site. Using BIM technology to analyze the climate and the environment of the site such as Weather Tool of Ecotect Analysis (a BIM software) can transfer the two-dimension digital information of the meteorological data to images. Besides, the solar radiation can be analyzed through Weather Tool which can simulate the yearly solar radiation of different building orientations in the site and figure out the best orientation according to the amount of heat radiated by the sun during the overheated and over-cold periods of a whole year. In terms of building shape and facade designing, shape coefficient of building should be controlled under 0.3 to reach an ideal energy-saving shape. The second thing to consider is the plan combination, building shape and spacial designing. Using BIM to build a model can optimize the
layout of a complex or rooms and choose the best mixed scheme with the goal of natural ventilation and natural lighting. Particularly, it is imperative to create good natural ventilation, build a circulation system of natural air and design rational building intervals. Figure 2 shows what BIM software produces, namely the range of sunlight shadows of a simulated architectural complex from 8:00 to 16:00 in the winter solstice and part of screenshots of sunlight data analysis table in some buildings.

Using the function of “Range of Shadows” in the Ecotect Analysis (BIM software) can simulate the sunlight of the designing model and analyze the data. Besides, the shadow at any time can be observed. In addition, the function can combine the regulations of fire protection and building designing to calculate the building interval.
4.2. Application of BIM technology in the initial phase of designing Building

In this phase, the designing documents need to be finished, including designing drawings (optimizing some drawings made in the former phase), primary facilities, material lists and books of engineering budget. Besides, BIM technology is applied to simulating the wind, light, heat, sound and energy conditions of the post-construction project and undertaking building performance simulation. In the simulation process, software used is as follows. The functions of Software CFD, namely Fluent, SAR-CCM+ and Phoinix, are used to simulate the natural ventilation while Ecotect Analysis is often utilized to simulate natural lighting. When it comes to the simulation analysis of heat (temperature, radiant quantity and sunlight), such software as Autodesk Ecotect Analysis, Ansys Fluent and SUNSHINE are applied. Figure 3 shows the screenshot of the distribution diagram for simulated daylight coefficient and the data analysis table of each room on a building floor.

![Figure 3. The simulated daylight coefficient distribution and the data analysis of each room on a building floor](image)

| floor no. | Room number | Room type | Daylighting grade | Daylighting type | Room area (m²) | Daylighting coefficient C (%) | Standard value of daylighting coefficient (%) | Meet the requirements or not |
|-----------|-------------|-----------|-------------------|------------------|----------------|-------------------------------|---------------------------------|----------------------------|
| 2          | Ordinary classroom | III | mixed | 69.67 | 3.62 | 2.00 | Yes |
| 2004       | office | III | mixed | 22.48 | 2.99 | 2.00 | Yes |
| 2006       | office | III | lateral | 18.60 | 3.63 | 3.00 | Yes |
| 2007       | office | III | lateral | 14.88 | 3.69 | 3.00 | Yes |
| 2009       | toilet | V | lateral | 2.64 | 2.82 | 1.00 | Yes |
| 2010       | toilet | V | lateral | 2.70 | 2.72 | 1.00 | Yes |

By adjusting diameters like the simulated building’ shape, orientation, sunshade, window to wall ratio and envelope structure, the expected operation effects after the building completion can be analyzed and evaluated; and besides, it is necessary to adopt technological measures to optimize the building designing so as to reach the upgrading level of green architecture. [5]

In terms of controlling the cost of an overall estimate of project construction, various project parameters and engineering quantities of the project can be obtained at this phase by the BIM model which can combine the project parameters and engineering quantities, inquire the index database or
the estimate database and figure out the reasonable estimate price. The BIM model can simulate different design schemes and designers can undertake the reasonable value engineering and the quota designing. As for the usage of building materials, natural materials, low or non-toxic materials building materials with no formaldehyde or with the least VOC content should be used as much as possible in the design, since the cost of building materials for general construction projects accounts for more than half of the total cost. Besides, using more renewable materials like Wood, waste paper and scrap metal can both reduce the building cost and reduce the negative effects on the environment.

4.3. Application of BIM technology in the phase of designing construction drawing

Building

In the process of designing buildings, it is usual to encounter designing changes, mistakes, omissions and deficiencies. As a matter of fact, it is a very common phenomenon in this field that the design of a building needs to be repeatedly modified. It often takes a lot of time and efforts to design the plan by the traditional methods and even worse, the plan tends to fail to reach the satisfactory effects. There are most problems found in such aspects as structural collision and pipeline integration of equipment. Using BIM software to implement 3D roaming technology in designing green architecture can avoid errors, omissions and defects to reduce the probability of resource waste to a large extent. Figure 4 shows the use of comprehensive collision technology to check the internal pipeline collision situation of the building project and the analysis table. It aims to find out problems and to solve them.

In the phase of designing construction drawings, especially the designing process of leveling, erecting, and cross-sectional deepening, BIM modeling software which features a real-time updating function enables designers to correct the errors and then it can update the drawing automatically. This advantage reduces repetitive work and greatly improves the designing efficiency.

5. Conclusions

As the problems caused by industrial civilization have become increasingly serious such as national resource shortage, environmental pollution and global warming, green architecture, as an important
development mode in the future, will encounter many problems and bottlenecks in its designing process. Fortunately, Building Information Modeling (BIM) technology can help address a number of the problems when people design the building layout, energy-saving functions and facility pipeline collision, analyze the energy consumption of buildings and optimize the designing. It can greatly improve the designing efficiency and quality, which is conducive to the healthy development of green architecture.

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