Building Information Modeling Application in Civil Engineering Field -- Take Gongbei Tunnel as an Example

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Abstract. Building Information Modelling (BIM), the direct product of digital technology, is now widely applied in the civil engineering field as a tool to enhance the overall construction project design and implement. Compared with Europe and the US, China has a later start in BIM technology, but has still achieved certain results in the past decade. Therefore, this research studies the application of BIM technology in the field of civil engineering and selects an example to analyze. This research reviews the development of BIM in China, revealing the broad development prospects in China's market. And by selecting the BIM application in Gongbei tunnel as an example, the detail functions of BIM software and their advantages are concluded: (1) Visualization of models; (2) Higher collaboration efficiency; (3) Higher cost management efficiency. This research can help promoting the future development of BIM in China.

Keywords: Building Information Modeling, Civil Engineering, Gongbei Tunnel.

1. Introduction

Building Information Modeling (BIM) is an emerging technology first born in the US. It has been developing and receiving attention from industries since the early 2000s [1]. According to the definition from the National Building Information Modeling Standard (NBIMS), BIM is a digital embodiment of the physical and functional characteristics of a facility. It is a knowledge resource, providing a process by which information about the facility is shared as a reliable basis for all decisions throughout the facility's life cycle (from its concept to completion). At different stages of the project, different stakeholders can insert, extract, update, and modify information in BIM to support and reflect the collaborative work of their respective responsibilities [2]. The appearance of BIM is changing the way of all parts involved in a project collaboration.

In China, the application of BIM is comparatively later than in developed countries. BIM was first introduced in China in 2004 and was promoted into the 12th Five-Year Plan in 2011 [3, 4]. In the next year, the China Academy of Building Sciences and relevant corporations initiated the establishment of the BIM Development Alliance to actively develop and build BIM technology and standards, as well as an innovation platform for software development in China [5]. Therefore, a deep analysis of the current situation and development trends of BIM application is of great research significance for promoting the application of BIM in the future.

Using the Gongbei tunnel as an example, this research discusses the definition and development of BIM in China. Finally, this research discusses the applications of BIM and illustrates them with reference to the Gongbei tunnel. However, due to practical issues, field investigation is not available, so this research only focuses on resorting and analyzing the existing articles. Further study can be done to acquire more accurate information if field investigations are carried.

2. Application of BIM in civil engineering

2.1 Visualization of structure design

Traditional civil engineering design still stays in the development mode of manual drawing, so three-dimensional (3D) designs are difficult to reflect in two-dimensional (2D) design drawings. Although more advanced structural design software has been developed, which can simply

demonstrate the 3D renderings [6], the visualization problem still exists. When 3D content such as the internal structure and pipeline layout of the building is involved, the rendering capability of the software is limited to meeting the 3D design requirements. Therefore, construction personnel always need to use their own imagination to finish their tasks. Besides, since most software is mainly customized for 2D design, its automatically generated 3D models are only for reference and do not support direct modification. Therefore, any further improvement to these models is difficult to carry out [7].

BIM technology makes up for this problem to a large extent. As BIM software is specifically developed for 3D design, designers can easily use the functions that are attached to the software to establish 3D models. In this way, construction personnel can have a direct reference basis when carrying out work [8].

2.2 Collaborative design of multiple departments

The operation of a civil engineering project requires the collaborative participation of multiple departments. To achieve a smooth process for the project, it is necessary to ensure collaborative work between different departments. All participating units must cooperate with each other effectively, and relevant resources must be shared to ensure the consistency of information throughout the project. However, in the actual process of the project, information asymmetry between different departments often happens. Once this issue cannot be resolved in time, the construction period of the project will be delayed, and the quality of the entire project will be adversely affected. With the application of BIM technology, this problem can be solved. Through the information-exchanging function of BIM software, the relevant building information can be integrated in real time, so that the personnel can directly input the completed information into the system and upload the overall data to the core data collector. So, the personnel of other departments can receive the project information feedback and solve the potential problems in time [9].

2.3 Application in cost management

For a construction project, appropriate cost management can positively promote the efficiency of accounting. For traditional cost management, cost engineers usually use two methods to carry out accounting. The first one is using computer software. The second method is carried out manually by inputting price information for each item into the software, which will process them and generate a result, which will then be collected. The accuracy of the calculation can be effectively guaranteed, but the defects of these two application methods are also relatively significant, which will waste a lot of time. The work efficiency is relatively low, which will have an adverse impact on the construction quality of the project. Besides, neither method is integrated with the whole project process, which means any change in the price or item number will make the past data invalid, so that the cost engineers need to do all the work again. Therefore, it is necessary to combine design drawings with calculation activities. With the application of BIM technology, this problem can be solved to a large extent. Because the models in the BIM system are modular, all the information about an item is closely linked with its ontology. Once one of the parameters fluctuates, the accounting result will immediately follow it without manual correction. Apart from that, necessary information can be directly inserted into the information database throughout the specific construction management process, allowing it to directly access the BIM model library, create a more detailed engineering flowchart and a new cost estimation procedure [10].

3. Example analysis

3.1 Project description

The Gongbei tunnel is located in the Gongbei port in Zhuhai, China (shown in Figure 1). It is a key project of the Zhuhai connecting line of the Hong Kong-Zhuhai-Macao Bridge (HZMB), with 2,741 meters in length and a design speed of 80km/h [11].



Figure 1. Location of Gongbei tunnel, from Google Maps

Because of the complexity and high risk of the project, during the construction of the Gongbei tunnel, BIM technologies were widely applied. This research selects this project to illustrate the application of BIM technologies.

3.2 BIM technologies applied in Gongbei tunnel

3.2.1 Parametric technique

The design team used Revit (a BIM software) to create BIM models of the tunnel. This project is a successful case of the application of BIM in the field of infrastructure. The project demonstrated how to use parametric technology to solve the technical problems of horizontal and vertical curves in complex tunnel design and can also serve as a 3D model (shown in Figure 2) for other relevant tunnel designs [12].

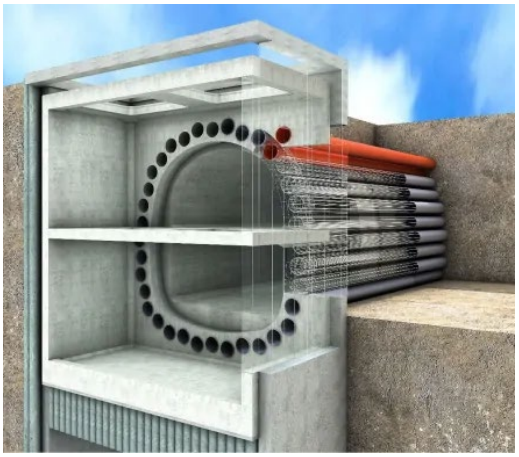


Figure 2. 3D model of Gongbei tunnel, from Hong Kong-Zhuhai-Macao Bridge Authority [12]

When a project operation is carried out, the design process is often affected by some uncertain factors, resulting in poor overall construction quality. For a large-scale project, any small problems in the design process may lead to delays in construction or even more serious engineering problems.

By applying a parametric technique, all the solid information can be stored as figures in the database. After the process of the computer, mathematical problems such as the design of horizontal and vertical curves can be rapidly solved with high accuracy, reducing the time cost of design.

Specifically, the cross section is divided into 3 large areas (shown in Figure 3) and 15 sub-areas (shown in Figure 4). The height of the steps is about 3.8m and the length is about 5m. With the aid of BIM, the team members can clearly distinguish different areas and carry out the following work. As this is a 3D model, team members can also drag the model's position to see the details of the inside structure of the tunnel.

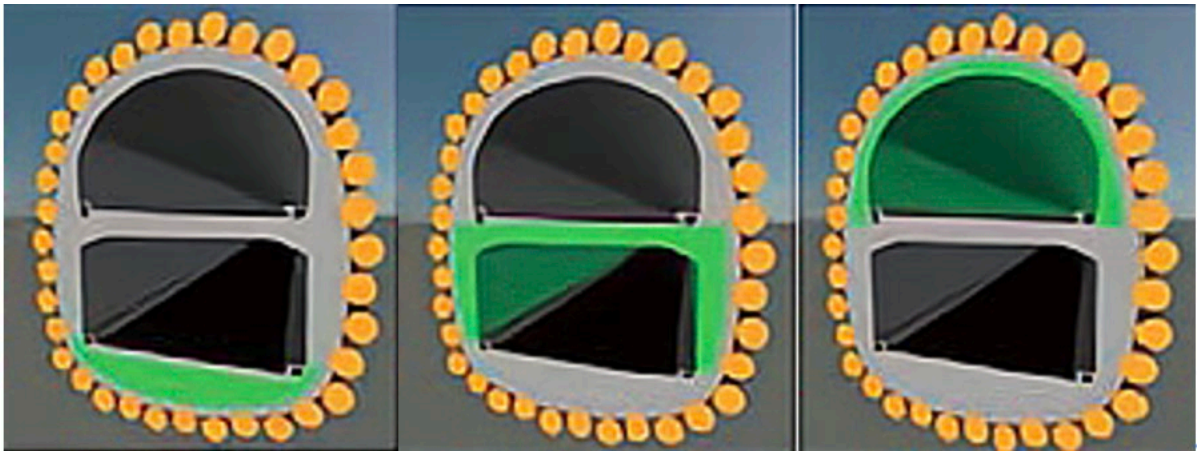


Figure 3. Separation of main areas of cross section of Gongbei tunnel, from Hong Kong-Zhuhai-Macao Bridge Authority

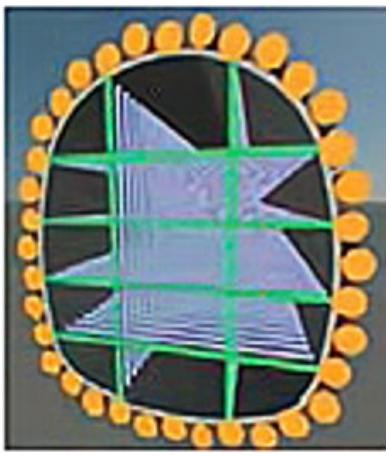


Figure 4. Separation of sub-areas of cross section of Gongbei tunnel, from Hong Kong-Zhuhai-Macao Bridge Authority

3.2.2 Life-cycle management

The application of BIM extends from the design and construction stage to the operation and maintenance stages, which is not only a breakthrough in the application of BIM, but also serves as a reference for the application of BIM in the field of operation and maintenance of other infrastructure industries. The lightweight application of HZMB proves that BIM's lightweight format is fully capable of supporting such large-scale, complex engineering applications, and the auxiliary development function proves that BIM data and systems need to be fully open, versatile, and flexible.

The team improved planning by simulating potential options at a specific level of detail. For example, in the Gongbei tunnel project, to establish a temperature monitoring system, the designers set monitoring points around the tunnel. Then, number the monitoring points and associate the temperature acquisition data with the BIM model components. The tunnel temperature monitoring system realizes the functions of temperature data correlation, temperature trend query, temperature warning, and risk location. Compared with the traditional model, the BIM technology-based tunnel temperature monitoring system can combine the 3D model for comprehensive analysis of historical data, monitoring point locations, and other aspects, and can more accurately and timely locate the location with abnormal temperature, so that the safety and quality of the project can be improved [12].

In the detailed design part of the workflow, cross-department collaboration is needed to optimize the efficiency in the design phase (shown in Figure 5). For example, the construction period of the Gongbei Tunnel project is strictly limited. By adopting Autodesk Navisworks (a BIM software), each department only needs to submit their own work period and requirements, then the software can automatically process the events and produce a construction plan. During the construction period, the

software can integrate the planned progress information of each department of the project (shown in Figure 6), focus on monitoring the construction progress implementation, and assist in the dynamic control of the construction process. When the progress of the implementation detected by the system is inconsistent with the plan, the system will take the initiative to prompt and continue to track the progress [12].

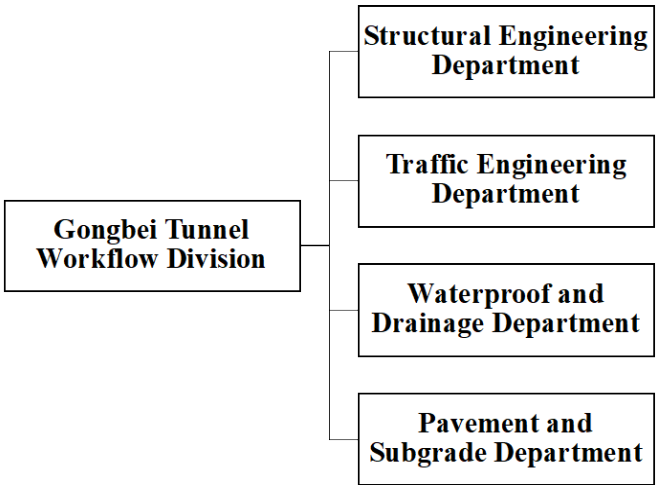


Figure 5. Gongbei tunnel workflow division, from Hong Kong-Zhuhai-Macao Bridge Authority

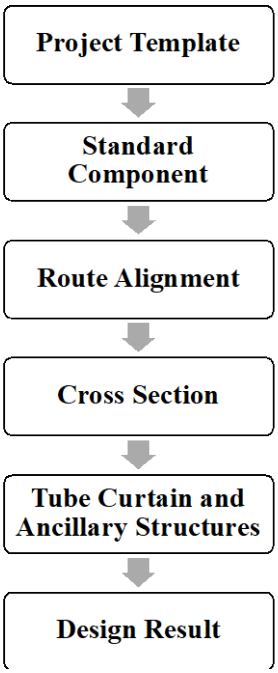


Figure 6. Gongbei tunnel design flow, from Hong Kong-Zhuhai-Macao Bridge Authority

4. Conclusions

In general, the application of BIM technology is still in its initial stage and faces various difficulties. But the advantages of BIM are significant, including visualization of models, higher collaboration efficiency, and higher cost management efficiency.

This research introduces the definition and the development of BIM in China. By selecting Gongbei tunnel as an example, the application of BIM technologies is well described. In this practice, the arrangement of each stage is very critical, and the relevant staff needs to be carefully and patiently treated to ensure the overall quality of the construction management work. Under these circumstances, the project team formulated 3D models, collaboration systems, and other related standards, which enhance the efficiency of the workflow and help with the establishment of the life-cycle maintenance

system. The BIM application experience in Gongbei tunnel can have a profound influence on the future BIM application.

The development of science and technology can always promote the development of the industry. After continuous practice, it has been proved that BIM technology is a high-quality data processing and analysis technology. The relevant application in civil engineering construction can display the relevant data in 3D form. In this way, relevant construction personnel can be assisted to become familiar with the construction content, problems and related deficiencies can be found in time during the formal construction process, and the related design can be effectively reduced. In this way, the construction period and cost of projects can be saved to a large extent. Nowadays, the development of BIM technology is making continuous progress, and it will be more effective in the future.

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