A study on the application of building information modeling technology in geotechnical engineering

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Abstract. Building information modeling (BIM) technology has brought significant changes to the construction industry, but its application in geotechnical engineering is still in its early stages. Despite challenges, an increasing number of professionals recognize the potential of BIM in geotechnical engineering. This paper studies the application of BIM technology in geotechnical engineering, including an analysis of BIM's characteristics, advantages, and challenges. It can be concluded that while facing complex underground environments, data acquisition difficulties, and compromised model accuracy, the integration of geological and soil data requires tools and standards, and subsurface and surface interactions demand intricate simulations. However, through secondary development, functional optimization, and advancements in exploration techniques, BIM still holds promise in geotechnical engineering. It aids assistant engineers in understanding subterranean environments, refining foundational designs, predicting issues, and facilitating construction management. Despite present hurdles, the application of BIM in geotechnical engineering is anticipated to grow gradually with the progress of technology, bringing forth more advantages and transformation.

Keywords: BIM, Geotechnical, Normalization, Application Prospect.

1. Introduction

Currently, geotechnical engineering is facing challenges such as non-standardized drawing information and a lack of a unified language to clearly convey geological information. Additionally, presenting a comprehensive geological picture to project investors solely through geotechnical knowledge and drawings is proving difficult. To facilitate collaborative design, virtual construction, simulation, and management processes, building information modeling (BIM) is gradually emerging as a vital tool in civil engineering. Its features of visualization, coordination, and virtualization align well with the needs of geotechnical aspects. However, existing BIM teams seem to overlook the geotechnical dimension of models, which could result in operational errors, particularly in infrastructure-based projects. An obstacle between BIM teams and geotechnical data providers lies in effectively extracting and absorbing data from archived geotechnical records, primarily existing in geotechnical formats [1]. This paper starts with the characteristics of BIM, associates it with the standardization of geotechnical engineering, and explores the application status of the software in geotechnical engineering. Besides, the paper also divides specific advantages and threats through SWOT analysis and proposes possible solutions based on the analysis results. The significance of this paper is to show that the application of BIM software in the field of geotechnical engineering can

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improve engineering efficiency, reduce errors, and provide better decision support at different stages of the project. However, it is important to note that appropriate software, training, and collaboration are still needed to ensure the correct integration of geological information and engineering models.

2. Background information

2.1. Characteristics of BIM

BIM is becoming an important tool for civil engineering in infrastructure design, construction, operations, and process management. The definition of BIM is varied, and because the emphasis is different, the definition of the National Project Committee on Building Information Modeling Standards is used in this paper. According to this definition, BIM is a digital representation of the physical and functional characteristics of a facility, and it is also a shared knowledge resource of information about a facility that forms a reliable basis for decision-making throughout its life cycle. Unlike manufacturing, the civil engineering industry cannot produce physical prototypes. As a result, the information-rich digital model provided by BIM enables visualization, simulation, and collaboration to achieve design optimization in the virtual world, reducing the possibility of unknowns and risks for all project participants.

2.1.1. Harmonization. To ensure the smooth development and implementation of geotechnical engineering, it is necessary for all professional construction teams to cooperate with each other. Before the emergence of BIM technology, all construction teams used drawings to communicate and negotiate with each other, which is low in efficiency and prone to deviation. The emergence of BIM technology breaks the traditional way of cooperation and communication, realizes the optimization of design schemes, eliminates the relevant design conflicts, and makes the design schemes more scientific. Each construction profession can use the BIM technology platform to understand the engineering information, so as to better coordinate the construction work of various professions [2].

2.1.2. Three-dimensional visualization. BIM technology can be applied to the foundation pit design. The virtual model of the foundation pit support design can be simulated by virtue of BIM's powerful model-building ability. Technicians use the simulation platform to complete the presentation and inspection of the model and understand the specific intent of the design scheme. By introducing a three-dimensional (3D) stereoscopic model into geotechnical engineering, technicians can use the first perspective to observe the 3D stereoscopic model of geotechnical engineering from multiple angles, so as to fully understand the details of geotechnical engineering and better optimize engineering design and construction [2].

2.1.3. Simulation. Simulation is an important feature of BIM technology. Through dynamic simulation, BIM technology can be better developed. In specific projects, some local construction difficulties are often encountered, and solving problems on site alone is very time-consuming and labor-intensive. Therefore, the dynamic simulation function of BIM can disassemble and simulate its complex processes, so as to better and clearly observe the causes of construction problems (see Figure 1). In the specific operation and implementation, the cost and time limit are combined to directly reflect the specific process of construction. The construction unit can not only master the construction process flexibly but also supervise the construction, coordinate the overall situation, and rationally allocate construction resources, so as to improve the quality and efficiency of the project, reduce unnecessary waste, and save project costs.

Figure 1. The whole picture of the Xin Jin Liang field simulated by BIM technology.

2.2. The application of BIM technology in geotechnical engineering

First, BIM software is now mainly used in the calculation and simulation of structural-engineering-related projects such as buildings, bridges, and tunnels, but its application in geotechnical engineering is relatively not mature enough, whether it is difficult to establish a family database in the geotechnical direction, or it is difficult to convert the acquired geological information from a point to a whole surface. These problems require the control and realization of its cost.

Second, in the field of geotechnical engineering, people usually use 2D drawings to convey information, which is slow and has errors in the communication between different departments. However, the visualization and coordination characteristics of BIM technology are expected to enable construction projects to be better expressed at the 3D level, so as to achieve the ideal goal of shortening the construction period and saving costs. For example, in traditional geotechnical engineering investigation, column charts, section maps, borehole plans, and investigation reports are generally adopted as investigation results, and these data are mostly saved in the forms of tables, texts, charts, and drawings, which seriously have shortcomings such as scattered data management, low sharing efficiency, and slow update speeds [3]. Therefore, in order to make the expression of geotechnical investigation results more intuitive and accurate, it is necessary to use advanced information technology to realize three-dimensional visualization of geotechnical investigation results. The rapid development of BIM technology in the field of construction engineering has undoubtedly brought inspiration to the information of geotechnical engineering investigation [4].

Third, BIM software still needs to be developed. At present, there are relatively mature data conversion interface software with Revit, which is generally structural analysis software, and Industry Foundation Classes (IFC) standards are also used for information exchange. The analysis software ANSYS and Revit, which are widely used in geotechnical engineering, have different file types and cannot exchange data directly. At the same time, the material parameters contained in the existing Revit modeling do not have the common parameters of geotechnical materials. These differences cause obstacles between the establishment of building information models and analysis and calculation for geotechnical materials, and the analysis of mechanical deformation characteristics of geotechnical materials is also limited [5]. By writing plug-ins such as Revit API and computer languages such as c++, secondary development can be effectively carried out to achieve a more efficient conversion.

3. An analysis of geotechnical application based on BIM

3.1. SWOT analysis

3.1.1. Strengthens. As shown in Figure 2, the main advantages of the combination of BIM technology and geotechnical engineering can be summarized as follows: the high visualization and virtualization characteristics of BIM can advance the virtual construction process of the project and improve the efficiency of the collaborative design of various departments, thereby achieving a faster and better standard of information transmission. In addition, BIM can convert traditional 2D transmission into 3D transmission, which also converts the poorly shared geotechnical information into a clear 3D model, which is a boon for both investors and departments that need to interface with geotechnical workers.

3.1.2. Weaknesses. The two do not fit. Different file types can make the subsequent calculation inspection impossible to be carried out. Most of the geotechnical data formats are usually hard copy, PDF, and image formats (such as jpg and tiff). These formats are difficult to retrieve and easy to lose and deteriorate due to physical damage. At the same time, they are difficult to be applied in the mechanical calculation software. In addition, it is hard to obtain complete and specific properties of geotechnical materials, which is also one of the application difficulties. The soil quality information obtained from one point or diagonal point of the project is not enough to accurately establish a 3D geological model, and the more complete information collection will bring greater costs.

3.1.3. Opportunities. BIM technology can better predict underground risks. It can predict the feasibility of the whole project through 3D geological models, such as the probability and treatment plan when encountering rocks or clay. It can also transfer the risks that should be borne by geotechnical engineers to investors, and it provides investors with a rough investment estimate of the project through the 3D model, which is a good help for financing and attracting investment

3.1.4. Threats. There may be some additional expenditure, mainly focusing on the training costs of existing geotechnical engineers on BIM software and the cost of introducing or leasing higher technology products to obtain geological information, similar to wave velocity detection methods. At the same time, there may be some legal disputes due to the uncertainty of geological conditions as well as the possibility of error-making of BIM software itself.

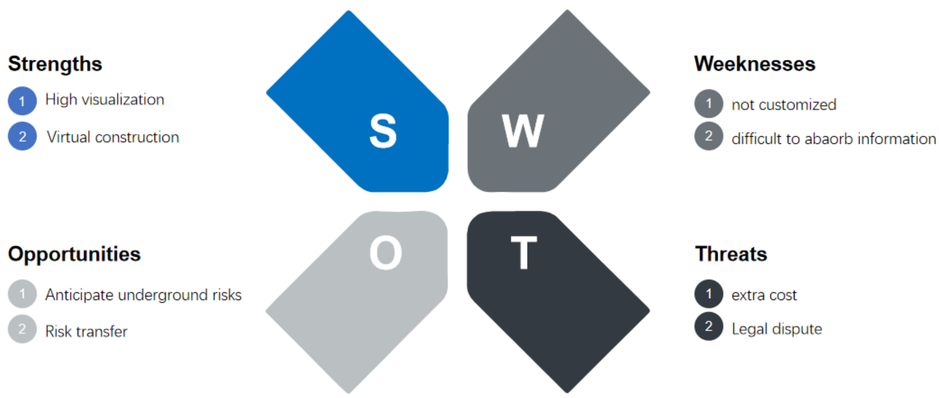

Figure 2. SWOT chart analysis.

3.2. Application problems and their solutions

3.2.1. BIM software compatibility issues and family library problems. The existing interface between ANSYS and Revit is very limited, and part of the conversion program is implemented by the IFC file as an intermediate bridge. This method has a lot of redundant information. It is difficult to assign material parameters, and the input model needs to be modified each time, so the applicability is poor. When using ANSYS software to calculate the geotechnical engineering model, it is easy to have some problems such as non-linearity of soil parameters.

Therefore, through Revit API interface technology, C# language can be used to read the complex Revit entity model and generate it in ANSYS, thus realizing the automatic conversion of the Revit model to the ANSYS model through successful analysis and calculation [5]. The key problem for the 3D geological model to reproduce the real terrain and strata is the lack of borehole data. The lack of borehole data will lead to a severely sharp angle of the 3D geological model, which is far from the actual situation. Therefore, the Kriging interpolation method can be used to predict the unknown spatial data values by using the known borehole data values and create a 3D geological model based on the idea of "point-generated surface and face-generated body".

3.2.2. Acquisition difficulties of geological information. At present, the reasons for the lack of geotechnical information in BIM are: (1) It is difficult to extract and absorb data from chaotic geotechnical investigation reports, which is time-consuming and prone to interpretation errors; (2) a centralized database that can make the data easily accessible is lacked. As a result, current methods for managing, archiving, and distributing geotechnical data need to be improved upon. Most current BIM models seem to start at the ground level, without considering the subsurface or treating the subsurface as a uniform substance (evenly distributed throughout). In this case, there are neither risks nor additional costs involved in changing the design scheme. However, the reality is quite different, the soil is never uniform and can vary greatly between sites that are closer together. The test results of the drilled samples are only relevant to that location, and, to a certain extent, the information inferred from the whole site is interpreted [6].

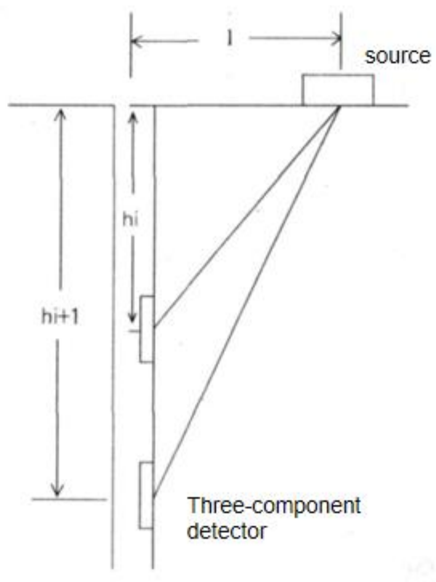

Figure 3. Schematic diagram of wave velocity test by single-hole layer detection method [6].

Figure 3 briefly describes the working principle and method of the wave velocity test method such as single-hole layer inspection. Wave velocity measurement technology is one of the seismic exploration methods, and it is also a simple, fast, and accurate in-situ measurement technology.

Through the wave velocity test, the elastic wave velocity of rock and soil can be obtained, which can provide the necessary dynamic elastic parameters for engineering design, classify the building site, and evaluate the seismic effect. Moreover, it can also estimate the site excellence period and the bearing capacity of the site soil, quantitatively classify the weathering degree of rock, and test the foundation reinforcement effect [6]. Through this method, relatively accurate geological information can be obtained more effectively and quickly, which undoubtedly plays a good role in the subsequent 3D model establishment.

4. Conclusion

At present, BIM technology has not been widely used in geotechnical engineering, and the current situation mainly plays an auxiliary role in the construction of existing projects to a certain extent. It is believed that with the continuous development of BIM technology and systems, the future application of BIM technology in geotechnical engineering will develop in the direction of refinement, standardization, and intelligence. By giving full play to the visual analysis technology of BIM, 3D geological models can be established, so as to more truly and comprehensively reflect the co-working effect of foundation and superstructure on the basis of coupling 3D geological models and engineering structural models. By summarizing the existing national and industry standards such as the Building Information Model Storage Standard and the Unified Coding and Basic Attribute Data Standard for Building Construction, it is essential to plan and establish standardized formats of geotechnical BIM data in advance and form a highly universal data storage format starting from enterprise standards and group standards. What is more, it is also critical to gradually incorporate into relevant national and industry standards, further improve the BIM standard system, and even strengthen the data integration of BIM model information of geotechnical engineering. By integrating BIM information of buildings and above-ground facilities and exploring the establishment of the basic platform of the urban information model, the development process of intelligent construction and green construction can be promoted, and cloud digitization of data can be realized. All of these will play a far-reaching role in the development of BIM technology.

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