

Visual analysis method of foundation pit monitoring information based on BIM platform

Xuan Ji¹, Hesong Hu^{1,*}, Dongli Lin¹, Lingsheng Tan¹, Mengxiong Tang²

¹ Guangzhou Institute of Building Science Co., Ltd., Guangzhou, 510440, China

² Guangzhou Municipal Construction Group Co., Ltd., Guangzhou 510030, China

*Corresponding Author e-mail: huhesong@gzsz.com.cn

Abstract. In order to visually express the safety monitoring information of foundation pits and underground engineering, realize the efficient management of massive dynamic safety monitoring information during the construction of foundation pits and underground engineering, as well as assist safety analysis, a building information model (BIM)-based Foundation pit and underground engineering dynamic safety monitoring information integration and network visualization method is proposed in the article. Firstly, the research builds a three-dimensional BIM model of foundation pit engineering based on the analysis of the element composition of the three-dimensional virtual scene of the foundation pit and underground engineering. Then, apply the method of key field mapping to establish the dynamic coupling between the BIM model and the safety monitoring information. Finally, the research realizes the virtual display of the construction process based on the three-dimensional visualization function of BIM technology. Furthermore, combined with the actual situation, the corresponding system is developed and applied in a certain project, which realized the visual integration of dynamic information of engineering safety monitoring and BIM under the network environment, and provided a support platform for the safety analysis of foundation pits and underground engineering.

Keywords: Foundation pit and underground engineering; BIM; Dynamic coupling; Safety monitoring; information visualization.

1. Introduction

With the development of China's economy, foundation pits and underground projects tend to be large-scale, and the scale of construction safety monitoring also tends to become more complicated. The amount of monitoring information generated is huge and the types are complex, which brings about difficulties for the understanding, analysis and management of monitoring information. With the continuous development of information technology, how to use information technology to realize the visualization, efficient analysis and management of safety monitoring data of foundation pits and underground engineering, so as to improve the understanding, application and efficiency management of monitoring data, has gradually become a demand and Trend [1-2].

In China, experts and scholars have done some research on the development of the monitoring visualization system of the Internet of Things, such as the visual remote structural safety monitoring system [3], through the secondary development of Auto CAD, the model display interface is embedded in the user interface of the monitoring system, so as to realize the visualization of model-based monitoring data. Another example is the three-dimensional visual bridge health monitoring system [4-6], it introduces three-dimensional image technology, which can realize the three-dimensional dynamic display of the bridge, and obviously improves the human-computer interaction, but the modeling process is too complicated to be suitable for large-scale structures. Another one is plug-in-based three-dimensional visualization system for structural safety monitoring [7-8], it provides structural models and scenes with a strong sense of reality, as well as data query and analysis functions, but the system lacks the interaction between models and data, and the modeling process is complex.

Looking at the current research results, the current research on the visualization of monitoring information has improved the legibility of the data by providing a structural model, and has reduced

the difficulty of understanding and analyzing the data. However, the existing structural model cannot be used, and repeated modeling is required. The problems of complex modeling or model visualization and poor interactivity cannot fully meet the requirements of monitoring information visualization. Therefore, looking for existing visualization modeling technology and establishing its data association with other Internet of Thing monitoring requires further research.

BIM technology is a research hotspot in the construction industry in recent years, and it is also the direct application of information technology in the construction industry. Applying BIM technology to the field of safety monitoring of foundation pits and underground engineering can effectively improve the level of monitoring information, realize the scientific organization and management of monitoring information, and improve the performance and efficiency of the safety monitoring system. Since BIM is able to provide a highly visualized model, make it can provide an ideal data graphic expression environment for safety monitoring. Through the association of monitoring data and models, the visualization of monitoring data in the BIM environment is realized, which reduces the difficulty of data understanding and improves the efficiency of safety analysis, evaluation and decision-making [9-11]. At the same time, BIM has strong information integration management capabilities, which can be used as a platform for monitoring information management and sharing, further to improve the management level of monitoring information [12-13].

The BIM core modeling software Revit has powerful model visualization capabilities and provides an open API. Therefore, using Revit as a development and application platform for monitoring information visualization and management has practical advantages.

2. Revit API interface

Revit provides API interface, and functions related to this interface include creating plug-ins, modifying model elements, automating operations on this basis, and developing third-party software to meet data analysis requirements. Revit provides the Revit SDK, which contains a lot of tools and class libraries. The relevant situation is shown in Figure 5.1 below. The Revit API is of great significance for improving the development speed.

RevitAPI needs to run normally under Revit operating conditions. Based on this tool, user-developed plug-ins can be added efficiently, and certain extension operations can be performed. RevitAPI also sets related specifications to extend Revit. RevitAPI.dll contains many methods for accessing applications, files, parameters in Revit. In addition, it also provides some application interfaces and other types of interfaces [14]. There are many kinds of interfaces of RevitAPIUI.dll assembly, mainly such as: Command-related interfaces, Selection, and TaskDialogs. It can be used to facilitate interactive operations in the application. Therefore, in the application, Revit can be accessed and extended based on RevitAPI, which requires special interfaces, such as IExternalcommand, extended interfaces, etc. [15].

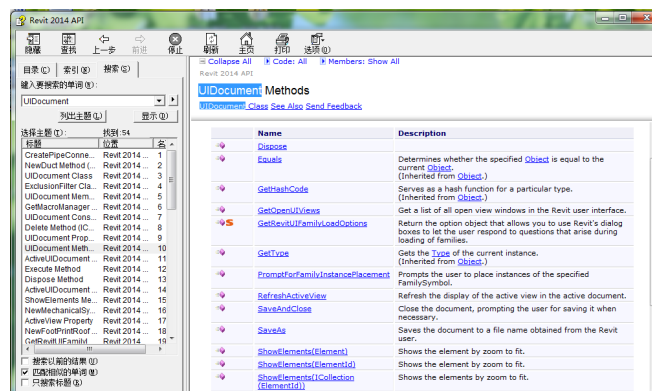


Figure 1. Revit API

The secondary development of Revit includes the following steps: 1. Create a new project; 2. Add necessary references; 3. Write source code; 4. Debug; 5. Plug-in registration; 6. Write panel code; 7. Panel registration.

3. BIM model of foundation pit

3.1 Modeling of foundation pit components

The BIM modeling of foundation pit engineering can be divided into 3 steps: The first step is to improve the component library of the engineering project family. When create building (structures) and various sensor models, we should give full play to the primitive characteristics based on the "family" in the Revit modeling process. However, the system family that comes with the Revit software does not cover all component models of the foundation pit project. For the family types already contained in the system family, they can be loaded and used directly in the project. For the family types not included in the system family, we need to use the family editor in Revit to independently create a family file (.rfa), create basic building component and define the corresponding attribute parameters of different types of components, such as geometric dimensions, material properties, etc., After the created family types loaded into the model project, a parameterized family component library is constituted. Figure 3 lists the family component models of some buildings (structures) in foundation pit engineering.

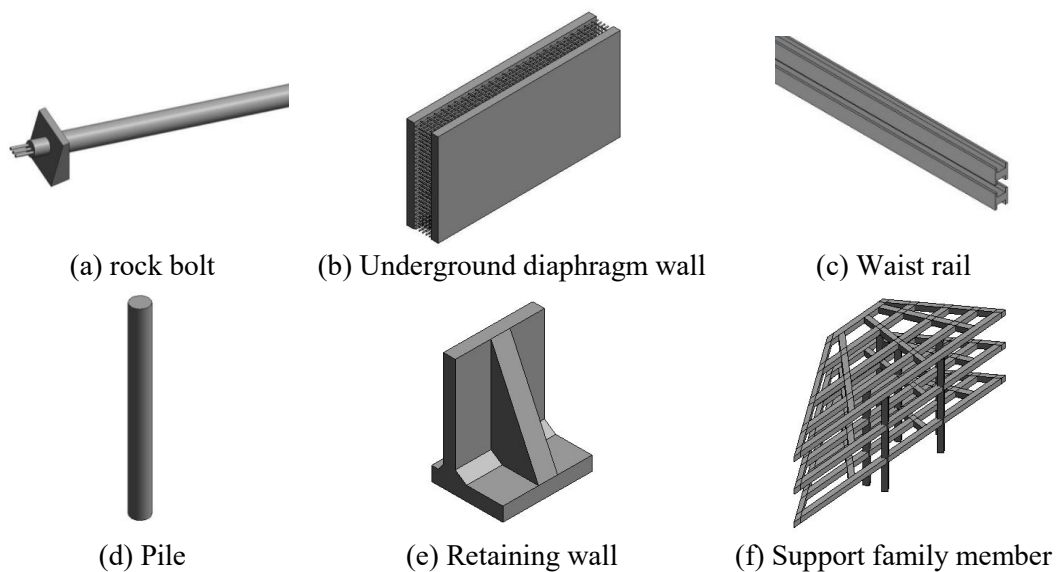


Figure 2. The group component model of foundation pit construction

The second step is to create a grid system for foundation pit engineering. Revit adopts the modeling method of placing components in the project, so it is necessary to establish a grid system according to the actual situation of the project to determine the starting and ending positions of component placement, describe the basic situation of the model size, and form a structural frame. The various elements of this project are integrated according to the actual space coordinates to ensure the consistency of the coordinates.

The third step is to place and adjust the component model. Modify the component parameters of the created family component according to the actual project and place it in the elevation grid system. Figure 2 is the component model established based on the grid. Add the basic information, structural attributes, size information, installation status of the component to the corresponding model, and set a specific ID for each component model. The BIM model automatically integrates attribute information and establishes a BIM model with integrated information to facilitate later Dynamic coupling of safety monitoring information and model.

3.2 topography and surrounding environment modeling

The topography in Revit belongs to site modeling, and the modeling method is different from the above-mentioned component model modeling steps. Determine the origin of coordinates and contour lines in Revit, use the "Topographic Surface" tool in the "Volume and Site" tab, and select the contour lines to create a topographic surface. Figure 3 shows the topography of the project and the surrounding environment.

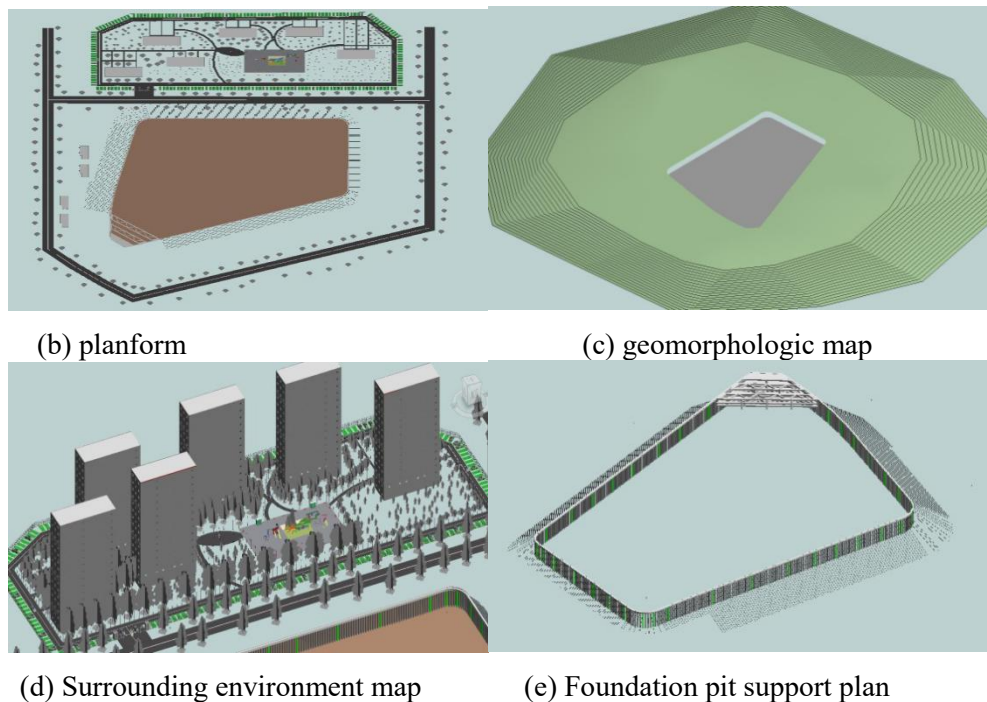


Figure 3. Terrain and surrounding environment modeling

3.3 Modeling of safety monitor

For all kinds of safety monitoring instruments, their appearance characteristics are not the focus of safety monitoring in foundation pit engineering, models of different shapes are used to distinguish the types of instruments, and the detection instruments are not rendered too much, as shown in Figure 4.

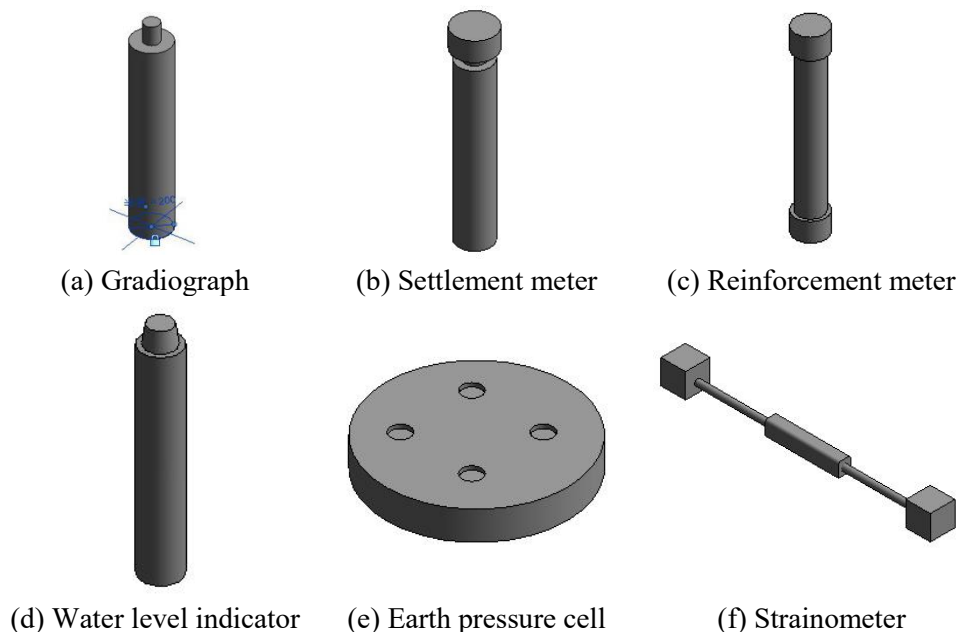


Figure 4. Monitoring instrument modeling

4. BIM model and dynamic safety monitoring information integration and visualization method

4.1 Collection and integration of monitoring data

The safety monitoring data collection of foundation pit engineering is divided into monitoring instrument collection and manual monitoring. Monitoring data such as pile settlement, deformation, and earth pressure are automatically collected and transmitted remotely by monitoring instruments. For some unexpected conditions on the construction site, when the monitoring data cannot be uploaded in real time, the engineers will monitor the settlement through leveling during inspections, supplementary collection of monitoring data is carried out through manual entry, which provides auxiliary support for the realization of data analysis, photo query and visual management of safety monitoring.

4.2 Dynamic coupling of BIM model and safety monitoring information

The safety monitoring information of foundation pit engineering is multi-source data. It is necessary to design the database reasonably, store these data and associate it with the BIM model. SQL Server is used as the database platform to centrally manage safety monitoring information data, store safety monitoring information data and three-dimensional models in the form of files, and store only the file path in the database. The organization structure of the dynamic coupling of the three-dimensional model and safety monitoring information is shown in Figure 5. Each safety monitoring instrument has a unique instrument tag number. The key field mapping method is used to establish a one-to-one correspondence between the safety monitoring instrument tag number and the BIM model ID of the monitoring instrument. The original monitoring data and instrument information can be linked to the BIM model through field of the monitoring instrument tag number, thereby realizing the dynamic coupling of the BIM model and safety monitoring information.

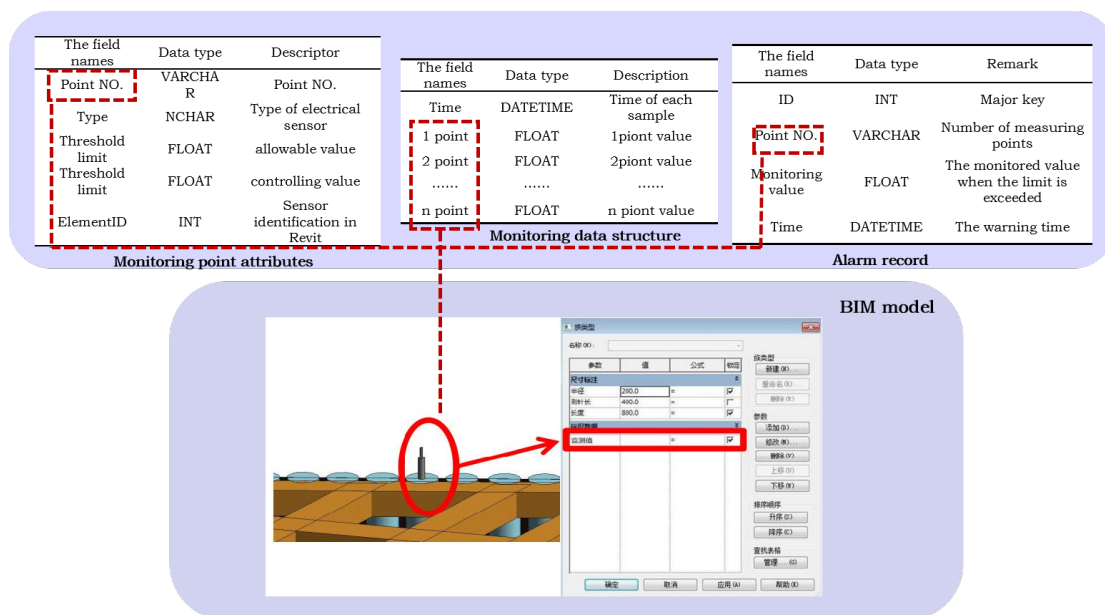


Figure 5. Add a monitoring value attribute to sensor attributes

4.3 Network visualization of BIM model for foundation pit engineering

By setting up the RevitAPI secondary development environment, the monitoring information visualization management system is developed, it divides the functions into four parts: data storage and analysis, monitoring information management, program reports, and real-time roaming. Based on C# programming, database development and other computer technologies, the interface and functions of each module is designed and implemented. Among them, the data conversion module

will realize the seamless connection between the Internet of Things monitoring and the BIM data platform, and collect engineering safety data information in real time. The intelligent analysis module processes and analyzes the original data, evaluates the safety of the project based on the stability of the foundation pit, the theory of multiplication analysis and related specifications, so as to predicts unsafe factors and generates a real-time correction plan. The real-time roaming module generates 3D roaming effects according to the user's selected time range, visually observes the monitoring results from different angles and colors, enhances the visibility of the monitoring results, and reduces the difficulty for understanding and analyzing monitoring data.

4.4 Visual analysis of dynamic safety monitoring

According to the BIM technology and network visualization platform, a 3D model is established to display information such as engineering structure and virtual scenes, and the operation and control of the BIM model and 3D virtual scenes of the engineering are controlled through browser controls to realize basic view operations such as zooming in, zooming out, translation, and rotation. Click on the monitoring instrument model or query the monitoring instrument through conditional filtering. The position of the monitoring instrument can be focused in the 3D virtual scene, and the input model attribute information when the BIM model is established is displayed at the same time, so as to realize visual expression of the basic information, structural attributes, design number, and installation status of the component. According to the dynamic coupling of the BIM model and safety monitoring information, the monitoring data can be consulted in real time to help managers make quick decisions. Related design documents (safety monitoring layout drawings, equipment installation drawings, etc.) can provide download interfaces to facilitate further analysis of safety monitoring of water delivery projects. At the same time, further statistical analysis, report output, and timing diagram drawing of safety monitoring data can be performed to achieve three-dimensional visualized management of safety monitoring information.

5. Engineering Applications

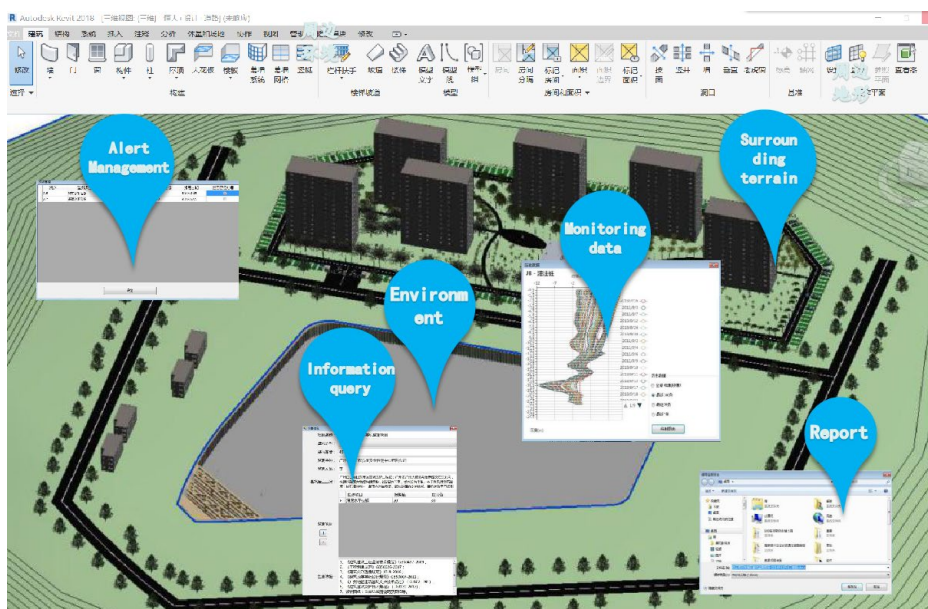


Figure 6. Visual management of safety monitoring

Based on the above research content, taking a foundation pit project in Guangzhou as an example, a safety monitoring information integration platform is developed. By using the methods described above, the project 3D BIM model is established, and the 3D BIM model is integrated on the platform according to actual coordinates, which can visually show the actual topography of the project area and realize the visual analysis of the safe operation of foundation pit projects. Figure6 shows the

safety monitoring information query process. We can focus on the model in the 3D virtual scene by directly clicking the monitoring instrument model or clicking the model name of the model browser on the left, also we can view the monitoring time of the monitoring instrument, the physical quantity of the current monitoring data and Timing chart in the near future.

6. Conclusion

The types and quantities of buildings and monitoring equipment surrounding the foundation pit project is complicated, therefore the safety monitoring of foundation pit project will generate a large amount of monitoring information. The existing safety monitoring management data expression is not intuitive enough, the visualization integration effect is poor, and the dynamic visualization management of the foundation pit engineering monitoring data is not realized. In response to the above problems, BIM technology is used to establish a three-dimensional BIM model of water delivery engineering project, it explains the modeling methods and expression forms of different types of components, and completes the integration of component information through the adjustment of component attributes in the modeling; combined with database technology to realize safety monitoring information Integration, using model ID and component number one-to-one mapping method to realize the dynamic coupling of BIM model and safety monitoring information, further to realize the visual analysis of dynamic safety monitoring information. The management platform is developed based on the specific conditions of Guangzhou foundation pit engineering. In summary, the system worked well, realizing dynamic, intuitive and efficient management and analysis of the dynamic safety monitoring of foundation pit engineering, which providing a decision-making platform for the safety monitoring and analysis of foundation pit and underground engineering.

Acknowledgments

The research described in this paper was financially supported by the Science and Technology Program of Guangdong Province (Granted No 2021A0505080009& 20200610102337909/AGJ), Science and technology planning project of Guangzhou Municipal Construction Group Co., Ltd (Granted No 2021-KJ012), Guangzhou science and technology projects (Granted No 202103000038), science and Technology Project of Guangdong Provincial Department of Housing and Urban-Rural Development (2020-K38-351484).

References

- [1] Ying Shen, Xu Yifan, Li Chengpeng, Guo Renzhong, Li Lin. Easement spatialization with two cases based on LADM and BIM [J]. Land Use Policy, 2021, 109.
- [2] Alwan Zaid, Nawarathna Amalka, Ayman Rana, Zhu Mingyu, ElGhazi Yomna. Framework for parametric assessment of operational and embodied energy impacts utilising BIM [J]. Journal of Building Engineering, 2021, 42.
- [3] Wong Chong Oscar, Zhang Jiansong. Logic representation and reasoning for automated BIM analysis to support automation in offsite construction [J]. Automation in Construction, 2021, 129.
- [4] Zhao Na. Research on the Management Mode of EPC Project of Prefabricated Building Based on BIM Technology [J]. Open Access Library Journal, 2021, 08(07): 85-98.
- [5] Junxing Yang. Application of BIM Technology in High Formwork Engineering [J]. International Core Journal of Engineering, 2021, 7(7): 112-123.
- [6] Pereira Pimentel Augusto, Buzzo Marcio, Zimmermann Ingrid, Neto Huckembeck Frederico, Malgarezi Hellisson. A Descriptive 3D City Information Model Built From Infrastructure BIM: Capacity Building as a Strategy for Implementation [J]. International Journal of E-Planning Research (IJEPR), 2021, 10(4): 145-156.

- [7] Sharafat Abubakar, Khan Muhammad Shoaib, Latif Kamran, Tanoli Waqas Arshad, Park Wonyoung, Seo Jongwon. BIM-GIS-Based Integrated Framework for Underground Utility Management System for Earthwork Operations [J]. *Applied Sciences*, 2021, 11(12): 24-39.
- [8] Gongyu Hou, Le Li, Zhedong Xu, Qinhuang Chen, Yijun Liu, Bing Qiu. A BIM-Based Visual Warning Management System for Structural Health Monitoring Integrated with LSTM Network [J]. *KSCE Journal of Civil Engineering*, 2021.
- [9] Meyer T., Brunn A., Stilla U. ACCURACY INVESTIGATION ON IMAGE-BASED CHANGE DETECTION FOR BIM COMPLIANT INDOOR MODELS [J]. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2021.
- [10] Ding Hongliang, Li Xiangxin, Wang Xiaowei. Research on the application of a new type of reaction device in the horizontal bearing capacity test of a single pile [J]. *Guangzhou Architecture*, 2021, 49(03): 39-44.
- [11] Liu Xiaojun, He Changyan, Zhao Hantao, Jia Jinyuan, Liu Chang. Building information modeling indoor path planning: A lightweight approach for complex BIM building [J]. *Computer Animation and Virtual Worlds*, 2021, 32(3-4): 15-28.
- [12] Dounas Theodoros, Lombardi Davide, Jabi Wassim. Framework for decentralised architectural design BIM and Blockchain integration [J]. *International Journal of Architectural Computing*, 2021, 19(2): 31-35.
- [13] Obi Lovelin, Awuzie Bankole, Obi Chukwudi, Omotayo Temitope S., Oke Adekunle, Osobajo Oluyomi. BIM for Deconstruction: An Interpretive Structural Model of Factors Influencing Implementation [J]. *Buildings*, 2021, 11(6): 25-35.
- [14] Zhao Yunfan, Deng Xueyuan, Lai Huahui. Reconstructing BIM from 2D structural drawings for existing buildings [J]. *Automation in Construction*, 2021, 128: 56-68.
- [15] Zhong Zhifeng. Research on the whole process information control technology of EPC Project based on BIM [J]. *Guangzhou architecture*, 2020, 48(04): 44-48.
- [16] Chen weiwen, zhao qian. Application of BIM technology in construction of special-shaped steel structure [J]. *Guangzhou architecture*, 2017, 45(02): 39-41.