Journal of Research in Science and Engineering (JRSE)
ISSN: 1656-1996 Volume-6, Issue-7, July 2024
DOI: 10.53469/jrse.2024.06(07).15

Tunnel Information Constructionzone

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Abstract: ***Tunnel construction as a typical geotechnical engineering, compared with other civil engineering, has the characteristics of high uncertainty, which brings great challenges to the early design, middle construction and late operation. The so-called tunnel information construction is mainly based on advanced geological prediction, monitoring and measurement data and other information, combined with the actual geological description in the excavation process, timely decision-making on the site, rapid change of construction methods, or adjustment of support structure, in order to adapt to changes in geological conditions, so as to achieve dynamic feedback construction. Because of the advantages of tunnel information construction in modern tunnel construction, and there are many successful cases at home and abroad, it is necessary to have a systematic understanding of it. Based on the above background, the research status and successful cases of tunnel informatization construction at home and abroad are summarized. Mainly summarized in the following aspects: the application of BIM technology, monitoring and measurement technology and information management of intelligent, advanced geological forecasting.***

Keywords: Tunnel informatization, Monitoring measurement, Advanced geological prediction, BIM**.**

1. Introduction

In recent years, China's tunnel construction has entered a period of rapid development, and is transforming from a tunnel country to a tunnel power. 2020 China's tunnel construction industry market size of 400.83 billion yuan, an increase of 25.6%, 2021 China's tunnel construction market size of about 375 billion yuan, in the past ten years, China's tunnel and underground engineering construction business has a rapid development, not only in the number of tunnels, tunnel length growth, And in technology has also been rapid development, in the application of various construction methods have also made continuous breakthroughs. The specific performance is: the proportion of China's special mountain tunnels continues to increase, the rapid development of underwater tunnels, the underground development of urban roads, and the tunnel section is getting larger and larger.

Tunnels and underground projects play an increasingly important role in the three major challenges of population growth, resource shortage and environmental deterioration, because they basically do not occupy land resources. However, due to the characteristics of tunnel engineering, such as high risk, difficult construction management and large amount of information, the traditional analytical and numerical calculation can not be directly used to guide the construction because the parameter model is far from the actual. Human experience also has great blindness. The modern tunnel theory represented by "New Austrian Method" and "observation method construction" attaches great importance to the rapid acquisition and analysis of surrounding rock information during construction, and is used to guide construction. Information-based construction has become the mainstream trend of tunnel construction. Huang Min [1] believes that tunnel information construction is an important idea to ensure the safety of tunnel construction, in which monitoring information collection and monitoring information management are the main contents of information construction, and also the core of tunnel monitoring information management system. In view of the low management efficiency of massive information in tunnel construction, the inaccurate analysis of monitoring data and the lack of timely warning and prediction of structural safety, we can grasp the safety status of tunnel structure in real time through the monitoring and measurement of tunnel, and achieve the informatization of construction process. Among them, the level of information management directly affects the monitoring and measurement function, and is an important symbol of the construction quality of the project, which must be highly valued by the engineering personnel.

2. Intelligent Monitoring Technology and Information Management

At present, in addition to traditional monitoring technology, optical fiber sensing technology, 3D laser scanning technology, digital close-range photography technology and other intelligent monitoring technologies are mainly used in tunnel engineering.

Optical fiber sensing technology began in the 1970s, and optical fiber sensing technology is an important symbol to measure the degree of information technology of a country. The basic working principle is to send the light from the light source through the fiber into the modulator, so that the parameters to be measured and enter the modulation area of the light interaction, resulting in changes in the optical properties of the light (such as light intensity, wavelength, frequency, phase, polarization state, etc.), called the modulated signal light, using the measured impact on the transmission characteristics of the light to complete the measurement.

Zhao Xingguang et al. [2] used optical fiber sensing technology to deploy crack gauges and optical fiber strain gauges in existing tunnels, and monitored the strain of tunnel crack gauges under the influence of excavation near the foundation pit, and guided the safe and smooth completion of the project according to the monitoring results.

Three-dimensional laser scanning technology is a technology that began to appear in the mid-1990s, three-dimensional laser scanner through the principle of laser ranging, the laser is first

projected to the surface of the measured object, and then reflected back to the sensor in the scanner, the scanner calculates the distance between the object and the object, determines the position of the object in space, and obtains three-dimensional point cloud data. Its main advantages are its high density, high resolution, high precision data and easy to use.

Deng Hongliang et al. [3] used 3D laser scanning technology to obtain point cloud data in an all-round, high-precision and real-time manner in tunnel full-section monitoring, and analyzed the map.

Chen Mingan [4] used 3D laser scanning technology to enter the shield tunnel in the underpass area in Changsha Metro project

Line monitoring, greatly improve the monitoring efficiency.

Digital close range photography is a new 3D precision measurement technology. This technology is based on precision measurement, digital imaging, image recognition and processing, which further improves the level of measurement automation. With the improvement of the resolution of computer and digital imaging processing, the application of digital close-range photogrammetry in tunnel engineering monitoring and measurement becomes more and more mature.

Liu Changjun et al. [5] used close-range photogrammetry technology to quickly obtain information such as structural plane spacing and track length, and proved that this technology has a broad application prospect.

Wang Guohui et al. [6] used an ordinary camera to measure the convergence of the tunnel section, which comprehensively and intuitively reflected the displacement of the tunnel chamber with large deformation.

In order to improve the level and quality of monitoring and measurement, better play the role of information management, timely feedback and guidance of monitoring and measurement results to ensure tunnel construction quality and construction safety, domestic and foreign scholars have done a lot of work on tunnel monitoring information management system:

Qian Qihu [7] proposed that the future development direction of tunnel construction information technology could be to optimize the design, selection and construction of TBM and shield tunneling on the basis of big data (TBM/ shield construction data is a typical big data problem). It mainly uses big data technology to carry out data mining, data association analysis and machine learning to ensure the reasonable selection of equipment and the rationality of scheme selection in construction.

For example, TBM/ shield construction data is a typical big data problem. The torque of TBM/ shield is an important parameter for its selection, which is now based on the Japanese formula T=aD2, in which the influence parameter is single (only the outer diameter of the shield D). Due to its complexity, it is difficult to carry out theoretical research. Big data technology can be used to statistically mine the previous excavation construction parameters, analyze the variation rules of different types of shield tunneling parameters under different geological conditions, and obtain an empirical formula with strong applicability.

Zhang Junru et al. [8] believe that the collection and management of monitoring information is the main content of information construction, summarize common tunnel monitoring technologies and monitoring information management systems, and put forward tunnel health monitoring and intelligent information management evaluation system, which includes monitoring data collection, analysis, display, sharing and background management, structural health diagnosis, virtual simulation, etc.

Zhang Minqing, Wang Jiang, Wang Wanqi [9] et al. researched and developed a TBM construction information monitoring system, which can summarize and analyze construction progress, safety, quality and other data, as well as transmit and store information. Effectively improve the speed of communication between the construction site and management, and can better feedback and guide the construction.

Zhao Dong et al. [10] developed a tunnel monitoring information rapid feedback system based on Internet technology, and proposed for the first time the design concept that monitoring management system should serve decision makers. They adopted dynamic real-time monitoring classification combined with Internet technology to achieve rapid feedback monitoring information, so that decision makers could grasp the dynamic information of construction process monitoring in the first time. To a certain extent, the quality and level of monitoring management can be improved, and the practicability is strong.

Li Xingping [11] developed a tunnel engineering monitoring and measurement information management and analysis system based on previous work and combined with computer software technology. The system includes five modules: surrounding rock classification, data management, monitoring and early warning, image visualization and positive and negative finite element analysis. The data management module is the core of the whole system, which can realize the monitoring data input, analysis, query and other functions. The image visualization module provides a platform for the development of other image software in the future, and finally the system is successfully applied in practical projects.

3. Advanced Geological Forecasting Technology

Geological advance prediction is an important part of tunnel information construction. Its success is related to the safety of tunnel construction and the accurate evaluation of surrounding rock during construction. However, in the actual work, due to the technical level and management level, the forecast is not accurate, and the advantages of advanced geological forecasting technology are not really brought into play. Therefore, how to effectively and successfully carry out advanced geological forecasting work is the main problem of concern at present.

At present, advanced geological forecasting is mainly divided into long - term and short - term advanced geological forecasting. The short term advance prediction mainly includes geological sketch method, geological radar method, induced polarization method and so on. The long-term advance prediction mainly includes seismic reflection method, advance drilling method, surface geological survey method and so on. The most favorable for information-based construction is comprehensive geological forecasting, which cannot cover all aspects of the preceding forecasting methods. However, comprehensive geological forecasting can combine the above two or three forecasting methods, and establish the engineering information database of the tunnel according to the obtained information, so as to ensure the accuracy of prediction to the maximum extent, and infer and analyze the bad geological conditions ahead.

Qu Haifeng, Liu Zhigang, Zhu Hehua et al. [12] regarded the tunnel and its surrounding geological environment as a system, and proposed a comprehensive advanced geological prediction method based on three geological prediction technologies, including geological ground survey, geological radar and TSP prediction. It can accurately predict the type, scale and location of bad geology. It provides guidance significance for tunnel informatization construction.

Yang Huijun, Hu Chunlin, Chen Wenwu, Liang Shuiyun [13] et al made advance geological prediction of the basic geological characteristics of the fault and its fracture zone, and measured and analyzed the surrounding displacement of surrounding rock, subsidence of the arch roof, and pressure of surrounding rock. The dynamic feedback was given in the construction process, and the information construction of the fault fracture zone was realized.

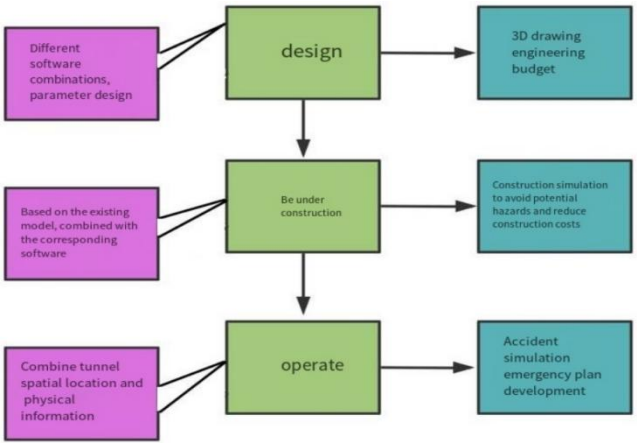
Li Shucai et al. [14] effectively solved the localization problem of water-bearing structure advanced detection during tunnel construction by using the technology of stimulated polarization advanced prediction, which can especially realize the estimation of water content in water bodies, expand the function of advanced geological prediction, and have good application prospect and popularization value.

Wu Wenrong [15] studied the combination of geological radar and geological sketch method as a practical comprehensive advance prediction method, and applied its advance prediction results to information construction. The method synthesizes the advantages of the two methods and overcomes their disadvantages. It is easy to operate and hardly occupies the tunnel construction time. At the same time, the situation of tunnel surrounding rock is collected comprehensively.

Zeng Shengqiang et al. [16] summarized the main methods of seismic reflection in tunnel advance prediction, including negative apparent velocity method, HSP horizontal acoustic wave profile technology, TSP tunnel earthquake prediction, TRT seismic tomography method, TST tunnel earthquake, CT imaging technology, etc. Due to the different observation systems and data processing methods of these methods, the inversion results are different. This paper mainly analyzes the differences of various seismic reflection methods in inversion, and evaluates the advantages and disadvantages of each method.

4. Application of BIM Technology

BIM (Building Information Modeling) technology was first proposed by Autodesk in 2002 and has been widely recognized by the industry worldwide. Qian Qihu proposed that the essence of BIM is to convert data into information, simulate the real information of buildings (tunnels) through digital information simulation, and use 3D virtual reality technology to model and realize visual engineering data model. It can help realize the integration of building information. From the design, construction and operation of the building to the end of the whole life cycle of the building, all kinds of information are always integrated in a 3D model information database. The design team, the construction unit, the facility operation department and the owner can work together based on BIM. Effectively improve work efficiency, save resources, reduce costs, in order to achieve sustainable development.



At present, BIM technology has played its advantages in various stages of the field of construction engineering, and promoted the progress of the field of construction engineering. But in tunnel engineering, its application is still in the initial stage. Some scholars have tried to apply BIM technology in the construction process of tunnel engineering, and have achieved certain application results. The research status is as follows:

Wanshifu [17] used Revit software as a modeling platform to build BIM model, optimized the defects of the original two-dimensional design, proposed the idea of combining BIM technology with monitoring and measurement technology, established a BIM-based information monitoring and visual alarm system, and realized the combination of settlement monitoring data and BIM model. The visualization of monitoring data is realized.

Liu Xunfang et al. [18] developed a management platform suitable for information-based tunnel construction based on BIM model, combined with the Internet of Things, big data, WebGL technology, computer programming and other technologies, and realized the work collaboration among all participants based on the same database model. Most of the functions of the platform are related to monitoring, schedule and other management, which basically realizes the automation of tunnel monitoring, can carry out real-time analysis of monitoring data and give certain processing opinions, as well as real-time control and correction of progress, and some also realize the accurate calculation of

cost and real-time control in construction.

Zhang Limao [19] proposed a BIM based risk identification expert system (B-RIES), which overcomes the inefficiency of traditional information extraction, reduces the dependence on domain experts, and promotes knowledge sharing and exchange between decentralized customers and domain experts.

Li Xue [20] carried out construction schedule management through auxiliary BIM model and BIM 5D software, and established a BIM-based tunnel construction schedule management model, namely BIM 4D model. You can understand the resource requirements, equipment requirements and capital requirements required for the next progress plan in advance; Supervise construction quality and safety issues in a timely manner, record defects on site, integrate data, correlate models, rectify or repair defects in a timely manner, and then inspect the project.

Marc- Antoine Vigneault [21] et al. studied the application of BIM technology in the cost management of tunnel construction, studied the application mode, implementation process and key technologies of BIM technology in cost management, and established a BIM-based construction cost management model, namely the BIM 5D model. The application shows that the introduction of BIM technology into the cost management of tunnel construction can achieve the effects of cost saving, quality assurance, and management improvement, and improve the accuracy and information level of cost management.

At present, there are still some problems in the application of BIM technology in tunnel engineering:

(1) Chaotic management mode. At present, the application of BIM technology in tunnel engineering is mainly concentrated in the design stage, and less in the construction and operation stage. This limits the communication between the various units, impedes the flow of information, and restricts the development of tunnel engineering BIM. The biggest advantage of BIM technology is its project information sharing, so that this building information model can be applied to the whole life cycle of the project. Therefore, the traditional DBB (design-bid-building) model needs to be changed.

(2) Inconsistent software platforms. BIM technology from the construction industry cannot be directly applied to the tunnel industry, as previous BIM-based software catered almost exclusively to the design of the construction industry and was inconsistent with tunnel engineering standards and software. Compared with the construction industry, tunnel engineering has more complex characteristics, including uneven terrain, large project scale, complex geological conditions, water gusher, weak surrounding rock and other unpredictable factors. Therefore, improving the software platform is of great significance for BIM technology in tunnel construction.

(3) The standard is vague. BIM technology is built on collaboration, but data exchange is still difficult due to different manufacturers. Many developed countries have developed appropriate standard systems. In our country, due to the short time of the introduction of BIM technology, the research on BIM standard is also relatively limited and the degree of localization is low. Currently, there is no BIM application standard specifically for tunnel engineering. Therefore, establishing a standard system has great promotion for the development of BIM in our country.

(4) Poor combination with GIS. GIS is short for geographic information system. Most of the tunnels in our country are built in mountainous areas, where the geology is complex and the terrain is diverse. Therefore, the application of BIM technology in tunnel engineering is more difficult. Different from construction engineering as an independent system, tunnel engineering is highly dependent on terrain and geographic information, so it needs to be highly integrated with GIS system. If BIM technology is combined with GIS, the BIM model is analyzed based on GIS geographic data, and the process of modeling and analysis will be greatly simplified.

(5) Poor understanding of BIM technology. At present, regardless of general construction or underground engineering, BIM technology is mainly applied to complex projects. Overall, few units incorporate BIM application technology into their designs, indicating a lack of awareness of BIM technology. BIM technology can not only shorten the construction period, reduce the construction cost; It is also important for the entire life cycle of the project. The BIM file is delivered to the operator after the completion of construction, which will provide great convenience for the later operation management and emergency.

5. Conclusion

Tunnel information construction is of great significance to improve the safety, operation efficiency and management level of the tunnel. However, there are still problems such as inconsistent technical standards, security risks and high input costs. In order to further promote the tunnel information construction, it is necessary to improve the technical standard system, strengthen the network security guarantee, and explore diversified financing methods. Tunnel information construction is an important part of modern tunnel construction. Through the introduction of advanced information technology, the safety, operation efficiency and management level of the tunnel can be improved, which is of great significance for promoting the development of transportation and protecting the safety of people's lives and property. However, the tunnel information construction still faces problems such as inconsistent technical standards, hidden safety risks and high input costs. Therefore, we need to further improve the technical standard system, strengthen network security, and explore diversified financing methods to promote the rapid development of tunnel information construction. Only in this way can we better play the role of tunnel information construction and make greater contributions to the development of transportation and social progress.

References

[1] Huang Min. Tunnel engineering Monitoring and safety Evaluation based on information construction and

intelligent management [J]. Highway, 2019, 68(01): 249-255.
[2] Zhang Minqing, Wang Jiang, Wang Wanqi, Yang Wei, JIA Dapeng. Research and Application of Information monitoring Technology for TBM construction of Railway tunnel [J]. Journal of Railway Engineering, 2022, 39(05):65-72.
[3] Zhang Junru, Yan Bo, Gong Yanfeng, Xu Jian, LIU Dingding. Research status and prospect of intelligent monitoring and information management system for tunnel engineering [J]. Journal of Underground Space and Engineering, 201, 17(02):567-579.
[4] Zeng Shengqiang, Feng Jianjun, Huang Yun. Application of seismic reflection method in tunnel advance prediction [J]. Sichuan Architecture, 2018, 38(03):119-120.
[5] Qian Q H. Main progress and development direction of geological forecasting and information technology for tunnel construction [J]. Tunnel Construction, 2017, 37(03):251-263.
[6] Chen M A. Massive data processing and application of laser scanning in subway shield tunnel [D]. Beijing Jiaotong University, 2016.
[7] Zhao Dong, Lv Kangcheng. Development and application of rapid feedback platform for tunnel monitoring and measurement based on Mobile Internet [J]. Traffic in the north, 2015 (11): 107-110. 2015.11.028.
[8] Deng Hongliang, Chen Kaijiang, Zhu Mingyan, Deng Qihua. Research on 3D laser scanning method and application of tunnel monitoring and measurement [J]. Bulletin of Surveying and Mapping, 2012(S1): 123-125+209.
[9] Li Shucai, Liu Bin, Li Shuchen, Zhang Qingsong, Nie Lichao, Li Liping, Xu Zhenhao, Zhong Shihang. Research on advanced detection of water-bearing geological structures in tunnel based on stimulated polarization method [J]. Chinese Journal of Rock Mechanics and Engineering, 2011, 30(07): 1297-1309.
[10] Liu Changjun, Ding Liuqian, Sun Dong-A. Automatic fuzzy clustering analysis and geometric information acquisition of rock mass structural plane based on laser point cloud data [J]. Chinese Journal of Rock Mechanics and Engineering, 2011, 30(02): 358-364.
[11] Li Xingping. Research on intelligent information management and analysis System for tunnel construction monitoring and measurement [D]. Chongqing Jiaotong University, 2008.
[12] Zhao Xingguang, Qiu Haitao. Application of fiber Bragg grating sensing technology in tunnel monitoring [J]. Chinese Journal of Rock Mechanics and Engineering, 2007(03): 587-593.
[13] Wu Wenrong. Research on tunnel advance prediction and Informatization construction application technology [D]. Tongji University, 2007.
[14] Qu Haifeng, Liu Zhigang, Zhu Hehua. Comprehensive advanced geological prediction technology in tunnel informatization construction [J]. Chinese Journal of Rock Mechanics and Engineering, 2006(06): 1246-1251.
[15] Wang Guohui, Ma Li, Peng Baofu. Application of new technology of digital close-range photogrammetry for monitoring tunnel chamber displacement [J]. Railway Construction, 2005, (11):42-43.
[16] Yang Huijun, Hu Chunlin, Chen Wenwu, Liang Shueyun. Information construction of tunnel in fault and fracture zone [J]. Chinese Journal of Rock Mechanics and Engineering, 2004(22):3917-3922.
[17] Shifu Wan. Based on BIM tunnel under wear both railway informatization construction management research [D]. Southwest Jiaotong University, 2021.
[18] Liu Xunfang. Research on Tunnel Dynamic Construction monitoring information System based on BIM and WEB [D]. Dalian Maritime University, 2017.
[19] Zhang L, Wu X, Ding L, et al. Bim-Based Risk Identification System In Tunnel Construction[J]. Journal of civil engineering and management, 2016(4):22.
[20] Li X, Xu J, Zhang Q . Research on Construction Schedule Management Based on BIM Technology[J]. Procedia Engineering, 2017, 174:657-667.
[21] Vigneault M A, Boton C, Chong H Y, et al. An Innovative Framework of 5D BIM Solutions for Construction Cost Management: A Systematic Review[J]. Archives of Computational Methods in Engineering, 2019.