Research on the informationized construction management analysis system of metro station with arch cover method

Master’s thesis

RESEARCH ON THE INFORMATIONIZED CONSTRUCTION MANAGEMENT ANALYSIS SYSTEM OF METRO STATION WITH ARCH COVER METHOD

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Content

Abstract：

With the deepening of urbanization and economic development in China, urban underground space has been developed and utilized in large quantities. As a new rail transportation method, subway has been built on a large scale in many cities and gradually becomes the hot spot of underground engineering in China. However, under the influence of various factors such as dense underground pipelines and complex geological conditions, the construction of urban subway is more difficult. For this reason, scholars have studied the construction method of subway station under the conditions of soft and hard geology, and summed up a new construction method called arch cover method. Due to the complexity of arch construction, information management in construction is very difficult, so it is of great significance to develop a set of information construction management analysis system according to the characteristics of arch construction. Based on the research background of Qingniwa Bridge Station of Dalian Metro Line 5, this paper focuses on the following contents through the research and summary of the current construction of arch cover method stations at home and abroad, construction information management system, multi-factor risk analysis technology and construction parameter optimization technology:

(1) According to automatic monitoring and database technology to build the dome cover subway station construction information automation management module, including the hardware module use for installation, earth pressure of construction, steel bar stress, strain and high sidewall convergence clearance of middle wall data acquisition, and the module used in the monitor information database structures. Finally, this module is used to analyze the variation trend of monitoring data and put forward relevant suggestions for the construction of the arch cover method station.

(2) This paper studies and builds the multi-factor fuzzy comprehensive evaluation module for risk analysis of arched metro station, introduces the multi-factor fuzzy evaluation technology of risk analysis used in the module, realizes the risk identification in the construction of arch cover method stations, and adds the construction risk index of arched metro station based on analytic hierarchy process. At the same time, this module can analyze and evaluate the construction risk factors of arch cover method stations, and finally put forward the corresponding risk countermeasures based on the analysis results of the module.

(3) The construction parameter optimization module of arch cover metro stations is developed. The module can set the optimization parameter range of particle swarm optimization program written in FISH language and call the optimization program. According to the orthogonal test and the numerical simulation results of the construction parameters of subway station, the regression model of optimization parameters and displacement is established, and the optimization design of the

construction support scheme of subway station is carried out by combining the supporting cost equation.

(4) The monitoring information management module, risk comprehensive evaluation module and construction parameter optimization module of subway station are integrated. Finally, the “Informationized Construction Management Analysis System of Metro Station with Arch Cover Method” was developed. In order to optimize the visual effect of subway station, the system introduced GIS related technology to realize the extended functions of station roaming and muck transportation.

Finally, the system was applied to the actual project of Qingniwa Bridge Station of Dalian Metro Line 5. The results showed that the monitoring data of the arch cover method station was managed in the system, and the risk hazard in the station was effectively controlled, and good results were achieved. The optimization effect of construction parameters. The system has certain application value in the construction management of metro station with arch cover method.

Key words: *arch cover method station; automatic monitoring; risk analysis; parameter optimization; system development*

1. Introduction

Due to the complexity of the arch cover method subway station construction, in order to realize the management and analysis of the construction information generated in the arch cover method subway station project, this paper independently developed and built the "arch cover method subway station information construction management analysis system", and It integrates relevant necessary functional modules. The system mainly includes the automatic collection and management module of arch cover method station construction information, the arch cover method station risk analysis multi-factor fuzzy evaluation module, and the arch cover method subway station construction parameter optimization module. The specific research content is as follows: This paper will divide into six chapters. A brief introduction of content of each chapter is described as following.

Chapter 1 is the introduction, which mainly introduces the research background and significance of this article, the main research content and the current research status of the research content at home and abroad.

Chapter 2 is the research on the construction management system of the metro station with the arch covering method, including the introduction of the construction management characteristics of the metro station with the arch covering method, the system development process, the function design and the key technology of the system.

Chapter 3 is the research on the automatic collection and management technology of the construction information of the arch-cover method station. First, the necessity of the construction monitoring of the arch-cover method station is analyzed, the multi-information automatic monitoring scheme of the metro station with the arch cover method is designed, and the automation is installed in the station constructed by the arch cover method. Monitoring equipment and analysis of the collected monitoring data, and finally integrated monitoring information analysis management module on the self-built visualization platform to manage the monitoring data.

Chapter 4 The fourth chapter is the multi-factor fuzzy evaluation technology of the arch-cover method station risk analysis. This chapter uses the analytic hierarchy process to classify the risks in the station, and then establishes the subway station construction risk evaluation index system, and calculates the weights of all levels of indicators by constructing a judgment matrix Based on the above-mentioned method, a multi-factor fuzzy evaluation module of arch-cover method station risk analysis is built based on the above-mentioned method to evaluate the occurrence probability and severity of the risk in station construction and divide the risk level with the fuzzy comprehensive evaluation method.

Chapter 5 is the construction parameter optimization technology of the arch method subway station. Taking the Qingniwa Bridge Station of Dalian Metro Line 5 as the engineering background, this chapter collects the relevant information of the subway station engineering, establishes the optimization model of the arch method subway station with particle swarm optimization algorithm, and establishes the adaptive value function of the support cost. Combined with the orthogonal design and numerical simulation method, the construction support parameters of the subway station are optimized to form a new support scheme for engineering use. Finally, the function modules of the above methods are integrated into the system.

Chapter 6 is the development and implementation of the integrated management analysis system. In this chapter, the functional modules developed in the first three chapters are integrated into the system, and the other functional modules in the informationized construction management analysis system of the arch cover subway station are introduced and applied in the project.

1.1. Research background and significance

In nearly a decade, China's social and economic development growth increasingly stable, but it continues to move forward the process of urbanization, especially the developed countries to promote rapid development time city policy, the city's public transportation is more and more in the direction of the underground development, especially the subway has become the domestic many large city's main traffic tools. In the past three decades, China has gone from three metro cities to 40 metro cities, and this number is expected to continue to rise in the coming years. As soon as possible in order to build efficient complete, smart green, safe and reliable new large and medium-sized city infrastructure service system modernization, "difference" plan is put forward to change the national infrastructure construction from high running speed to high quality, thus it can be seen in the city of the future infrastructure, urban rail transit will remain national key development projects.

Due to the dense buildings in the city, as well as the complex geological conditions and construction environment, the construction of subway stations is accompanied by great construction risks. The traditional open excavation method cannot solve this problem, so the construction of subway stations mostly uses the shallow buried excavation method[1]. The underground excavation method of subway station is mainly divided into pile method, middle column method, double-wall guide tunnel method and so on. In the face of the geological characteristics of Dalian, the upper is soft and the lower is hard, the traditional construction method of shallow buried excavation is not applicable, and a new construction method of shallow buried excavation — arch cover method is proposed based on the research of scholars[2]. In the construction of Dalian Metro Line 2, the arch cover method has been widely used. Researches by relevant scholars have found that the arch cover method with double primary branches can be better applied to the special upper soft and lower hard strata in Dalian, and the long-span single arch structure formed by the arch cover method can maintain stability[3-4]. The purpose of arch cover method is to divide the large section of subway station into several guide tunnels for distribution construction, so as to ensure the stability of the station structure. This method made full use of the lower bearing capacity and stability of the hard rock, the second line or the lining arch cover on both ends of the arch at the beginning of the bottom part of the button in the lower part of rock mass in the form of arch foot, at the same time, the second line or the lining arch at the beginning of the cover and can provide the bearing capacity for the upper soft soil layers to ensure the stability of the upper structure, the security and stability and settlement of small at the same time, guarantee the station the lower efficiency of excavation[5].

However, as a new construction method in recent years, due to the complexity of its construction method, arch cover method has resulted in the existence of large and diverse information data and potential construction risks, which need to consume a lot of time for analysis and management. Therefore, it is of great significance to develop a set of efficient and accurate information construction management analysis system based on the construction characteristics of subway station with arch cover method. This paper, taking dalian subway line 5 blue mud hollow bridge station as engineering background, building arch cover subway station informatization construction management analysis system for monitoring information management and analysis of the subway station, under this kind of construction method, we evaluate the risk of subway station, will build construction parameters optimization of arch, and form a supporting scheme, provide certain reference for the engineering construction.

1.2. Research status at home and abroad

1.2.1. Construction status of subway station with arch cover method

With the rapid development of domestic and foreign economy, the scale of urban subway construction is becoming larger and larger. Due to the influence of bad geology, the construction of underground excavation subway station has always been a difficulty in the field of subway construction. As a new construction method, the arch cover method can effectively make use of the stratum characteristics of "soft on the top and hard on the bottom" in some areas, and has been widely used in engineering. At present, the research on the construction of subway station with arch cover method is mainly divided into two kinds: numerical simulation and model test.

Aiming at the failure mechanism of surrounding rock in the construction of long-span tunnel with arch cover method, Zhao[6] systematically studied the failure phenomenon of surrounding rock when the load increased by using large-diameter model test. Taking Guiyang Metro Line 2 Provincial Hospital as the engineering background, Wang[7] used the numerical simulation method to simulate the tunnel construction process, and analyzed the adaptability of the arch cover method to the project through the distribution of plastic zone and settlement amount. Li KX[8] compared the construction sequence characteristics, applicable strata and construction time of different construction methods for large-span subway stations in hard rock environment. Based on the comparison results, he proposed the construction method of double side wall arch + lower step, and optimized the arch cover method of primary branch. Chen WL[9] to Qingdao metro line 1 the people's square station - between Hengshan road station as the background, using three-dimensional numerical calculation method of primary support to the arch cover to simulate the process step by step excavation, summed up the ground subsidence, primary support, vault subsidence, the changing rule of the stress and strain of surrounding rock, primary support arch cover method is verified in hard rock formation in the flat the feasibility of the application of large-span tunnel; Kong C[10] pays the number two subway in Guiyang Yang Ming temple single arch large-span subway station as the background, through the indoor model test, combined with finite element limit analysis method, comparison analysis under different working conditions at the beginning of the arch cover deformation law of surrounding rock in the construction process and the limit bearing capacity of arch structure of early provide theoretical guidance for design and construction of arch cover method; Zhao CY[11] combined with the "arch cover" construction of Qingdao Metro Line 4 People's Hall Station Project, through the numerical simulation method of the construction of the arch cover before the formation of the construction safety, risk and deformation law of the supporting structure and other contents, and will adjust the site construction scheme, according to the results verified its feasibility.

Although the predecessors have to arch cover to do a lot of research method of subway station construction, but because of the uncertainty of the subway station construction, under the engineering background of different construction problems encountered are not consistent, so for the purpose of this article on the arch cover construction of Dalian subway line 5 Qingniwa Bridge station engineering difficulties encountered in the analysis of management research.

1.2.2. The status quo of automatic monitoring and management information system of subway station

As information technology has achieved great results in various fields, the application of information management methods to subway construction monitoring has brought new research directions for the analysis of construction monitoring information. At present, whether at home or abroad, the management and control of subway station construction monitoring information is one of the research hotspots in the field of geotechnical engineering.

Domestic scholars have conducted related research on the monitoring information management system of subway station construction. Among them, Qiu DY[12] proposed to apply geographic information to the urban subway monitoring system, which designed and realized the visual query, calculation and spatial analysis of monitoring data. At the same time, it also has the functions of processing monitoring data and early warning, but the system lacks the analysis of monitoring data; Xie W[13] developed a subway construction monitoring information system composed of on-site manual monitoring and remote monitoring management systems, and established a new The data storage method was applied in the project; He YG[14] and Yu TG[15] both realized the web-side development of the urban subway construction monitoring information management system. The system not only realized the management of geospatial information, but also developed the subway construction Visual management of monitoring information, statistical analysis, safety warning and online information release; Li YH[16] and others carried out secondary development on the SuperMap Objects platform to realize remote real-time management of underground engineering monitoring information. At the same time, the system can also monitor electronic maps. Layers are edited and produced, and promoted in various tunnel projects.

Foreign Korean scholars Chungsik Yoo, Young-Woo Jeon, etc.[17] took the extension of Seoul Metro Line 3 as an example. Based on GIS technology, they studied the safety monitoring and risk management system in the subway construction process, and used the subway three-dimensional visualization of geography. The information system is integrated in various application systems in the form of modules or functions. The system can realize the common operation functions, dynamic labeling functions and monitoring and query functions in the geographic information system. The University of Rostock in Germany has developed a set of urban geographic information simulation system to realize the query, analysis and display functions of some infrastructure in the city. At present, more and more countries around the world are strengthening the research of automatic monitoring and management information systems, especially in the field of geotechnical engineering research. The Osaka Bay stratigraphic database has been established in the Osaka area of Japan for more than ten years. Information system, the number of boreholes reached 30,000.

It can be seen that with the development and integration of information technology and automated monitoring systems, realizing the informatization of subway station construction is the development trend of future construction. Although a large number of scholars have applied automatic monitoring technology and information management systems to the construction management of subway stations, these management systems are not suitable for all subway station construction, so a management analysis system based on the construction characteristics of the arch method is built. It is of great significance.

1.2.3. Status quo of multi-factor risk analysis technology for subway stations

With the rapid development of urban construction in China, the urban population is also growing rapidly, which also leads to large passenger flow, traffic congestion and building area shortage in many cities. To solve this problem, the city subway construction scale is becoming more and more widely in recent years, however, arch construction is subject to the subway station construction technology and the environment is complicated, large excavation section, buried depth and adjacent structures of many factors, such as construction risks are significant, so it is particularly important to the risk evaluation of subway construction.

At present, many domestic researchers have analyzed the risk generated by subway station construction projects, and conducted in-depth studies on the risk assessment methods to a certain extent. Taking the deep foundation pit of Zhengzhou rail transit station as the engineering background, Liu JW[18] et al. adopted the analytic hierarchy process (AHP) to construct the risk evaluation system of foundation pit construction, and used the fuzzy comprehensive evaluation theory to evaluate the potential risks in the construction of deep foundation pit. Taking Hefei Metro Line 1 as the engineering background, Ying GZ et al.[19] modified the established fuzzy comprehensive evaluation model through a nonlinear fuzzy operator that is in line with the characteristics of subway construction risk assessment, and evaluated and graded the risks in subway construction. Li ZY[20] such as a subway station foundation pit in Ningbo as an example, the WBS method is adopted in foundation pit engineering construction risk identification, then using the AHP method to establish a three-stage risk evaluation index system, construction of foundation pit by constructing judgment matrix calculating weights of indicators at all levels, the final evaluation index system of FCE method are used to get the value of each factor in risk assessment and risk grade divided into; Huang HW[21-22] et al. studied the risk management from subway construction to operation and put forward the risk factors existing in different stages of subway engineering as well as the basic ideas of risk analysis and countermeasures. Zhou HB[23] used fault tree method and comprehensive integrated evaluation method to identify and evaluate the risk factors of deep foundation pit construction in the background of a rail transit foundation pit project in Shanghai. Guo J[24] adopted the AHP method and expert investigation method to analyze the importance and main risks of subway station construction risk factors in soft soil area, and carried out risk assessment of the project by investigating the occurrence probability and loss degree of each risk factor. Zhao JX[25] combined set pair analysis method (SPA) and AHP method to construct the subway construction risk evaluation model. Liu B[26] built a risk evaluation index system for deep foundation pit construction on the basis of WBS-RBS construction risk identification, scored each risk factor in the index through the expert scoring method, and applied it to the actual project.

At the same time, foreign scholars have made a lot of contributions in the field of risk analysis of subway stations. Andrea[27] takes a deep-buried subway project under construction as an example to analyze the fire risk during subway construction by using simulation technology to analyze the changes of environmental parameters in the process of accident, and finally carries out risk assessment and the integration of results. Ding[28] introduced the development and application of a Web-based safety risk early warning system for urban subway construction. A hybrid data fusion model based on multiple information was adopted to simulate human experts to automatically provide safety risk assessment and early warning, which greatly improved information collection and sharing. Zhang[29] proposed a risk assessment model for subway construction based on interval number, calculated the risk level of each potential risk factor by using the calculation rules of interval number and membership function, and finally obtained the potential risk factors that need to implement risk prevention measures in the project, and applied this method in the actual project. Hyun[30] conducted risk analysis on subway engineering of shield TBM construction based on fault tree analysis and analytic hierarchy process, and made a comprehensive analysis on the probability and influence of risk occurrence and verified the effectiveness of this method by comparing it with field observation results.

To sum up, risk analysis plays a crucial role in the construction of subway stations. As a special construction method of arch cover construction, it is necessary to build a multi-factor fuzzy evaluation system for risk analysis of subway stations in order to ensure the construction safety of subway stations.

1.2.4. Present situation of optimization technology of construction parameters of subway station

Due to the characteristics of poor stability of surrounding rock, long construction period and wide influence area, the safety of the construction of subway station has been greatly reduced, and many construction accidents have occurred in recent years. However, the traditional support structure and construction method are not suitable for all underground projects, especially for the subway station constructed by the arch method, so the importance of the optimization of the construction parameters of the subway station for construction is self-evident.

At present, many researchers at home and abroad have done a lot of research on the optimization of construction parameters of subway stations. Wei SW[31] optimized and analyzed the spacing of steel supports in subway stations under reverse construction by means of numerical simulation and field monitoring data comparison, and finally achieved good economic benefits. Li YL[32] studied the mechanics and process optimization during the whole construction process of Nanjing subway tunnel with asymmetric small clear distance, and summarized the deformation characteristics, mechanical response and distribution law of plastic zone of the tunnel. Taking the blasting excavation of Huang-Fu interval tunnel of Shenzhen Metro Line 7 as the engineering background, Li Q[33] determined the prediction formula of engineering blasting vibration through theoretical calculation, and adjusted and optimized the construction method and related blasting parameters combined with field tests. Zhang T[34] combined with the engineering background of Wuhan Metro Line 3 and adopted FLAC^{3D} software and orthogonal experimental design method to optimize and analyze support parameters such as bolt length, bolt spacing and concrete grade in shield construction, forming a new support scheme for engineering use. Jiang[35-36] proposed an anchor parameter optimization method based on improved particle swarm optimization algorithm and orthogonal design scheme in view of the implicit nonlinear relationship between anchor parameters and the stability of surrounding rock, as well as the contradiction between the stability and economy of subway tunnel construction. Yan ZQ[37] took Qinghe Bridge Project of Beijing Metro Line 13 as the background, and optimized the mix ratio of jet grouting piles, grouting parameters, driving speed and other factors in the subway construction process by using the finite element analysis method. The optimal construction parameters were obtained and compared with on-site monitoring data to verify the rationality of the optimization results. Liu JW[38] optimized the excavation height and step length of the newly built foundation pit in Guimiao Road, Shenzhen City by simplifying the model. Chen WT[39] used FLAC^{3D} thermodynamic field-stress field coupling method to carry out numerical simulation of the tunnel net distance and the distance between double tunnel face, and finally obtained the optimal design scheme.

Because of the complexity of the construction method of subway station and the variability of the construction environment, scholars have done a lot of research on the optimization of construction parameters of subway station. With the popularity of the subway station in the city, this method will be used in more and more projects based on the superiority of the arch method, and the research on the construction parameters of the subway station under the arch method still needs to be further improved.

1.3. Research technical route

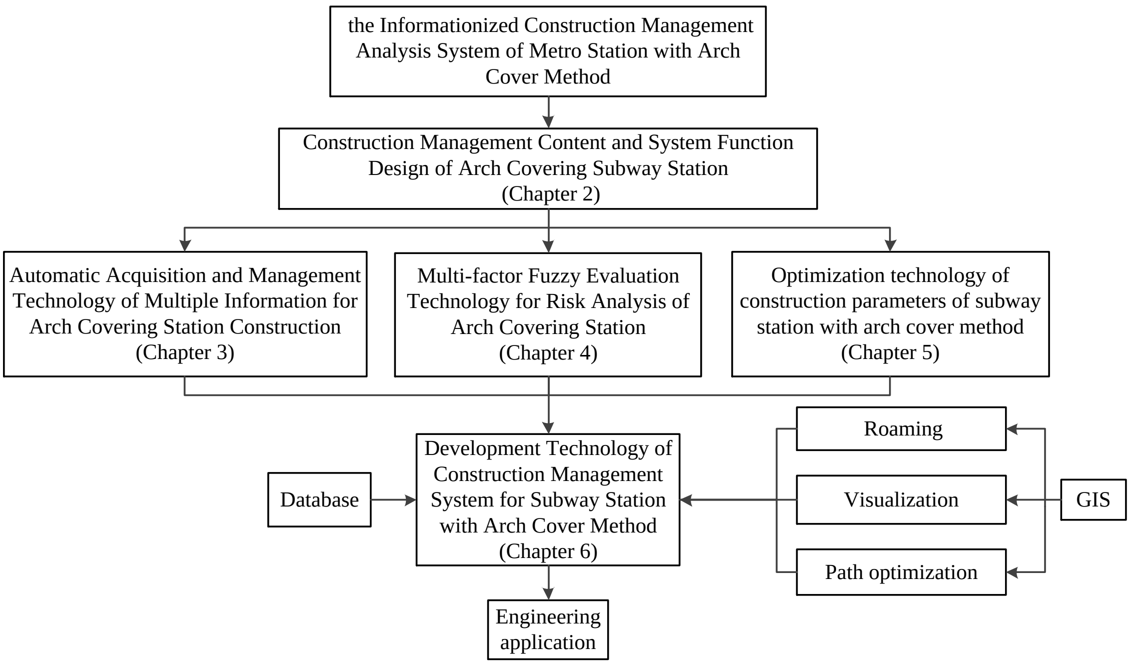


Figure 1.1 Technology roadmap

2. Design of metro station construction management system with arch cover method

2.1. introduction

Since entering the 21st century, especially in recent years, China has achieved rapid development in computer technology, communication technology, Internet of Things technology and geographic information system. At the same time, these technologies have been more and more widely used in all walks of life, which has achieved good results and greatly improved efficiency. Now also gradually to the informatization project construction, intelligent direction, but are mostly geared to the needs of some of the more common engineering and project, lack of pertinence, for a new method - arch cover method subway station engineering, there is still a lack of monitoring data management, risk analysis, parameter optimization operation for the integration of management analysis system. In this chapter, combining with the construction management characteristics of the arched metro station, the functional framework of the arched metro station information construction management analysis system developed in this paper is designed.

2.2. Construction Management of Metro Station with Arch Cover Method

2.2.1. Arch cover method subway station construction process

The construction of the main structure of Qingniwa Bridge Station should strictly follow the construction principle of shallow burying and underground excavation. At the same time, the main guide tunnel adopts the construction sequence of "first edge, then middle, strictly symmetrical", and the arch frame is erected in time and sprayed concrete is applied to ensure that the primary branch is closed and formed into a ring as soon as possible. In order to avoid large surface accumulation settlement, strict monitoring and measurement measures should be taken during the construction of the main guide tunnel, and construction parameters such as the length of the guide tunnel, the distance between adjacent guide tunnels and the support scheme should be dynamically adjusted according to the measured data. The schematic diagram of the construction process is shown in Table 2.1, and the specific construction process is detailed as follows:

(1) Build the No.1 and No.2 guide holes in the main body of the station and the leading small conduit in the arch between the guide holes, dig the main guide holes and provide initial support.

(2) After No. 1 and No. 2 guide tunnels are completed, steel pipe piles, crown beams and primary supports in the guide tunnels are constructed and concrete is backfilled. Then step method is used to excavate No. 3 and No. 4 guide tunnels, and the initial support of the first layer and the second layer of the station arch are applied successively.

(3) The main small guide tunnel and the initial support between the guide tunnel are dismantled in sections, and the waterproof layer of the station vault and the two-lined concrete structure are constructed in turn.

(4) Excavate the design elevation from the substructure of the main body of the station to the bottom of the pit in layers and sections, and timely support the side wall of the station. When the occurrence of slates tends to the inner side of the main body of the station, two prestressed anchor cables are set.

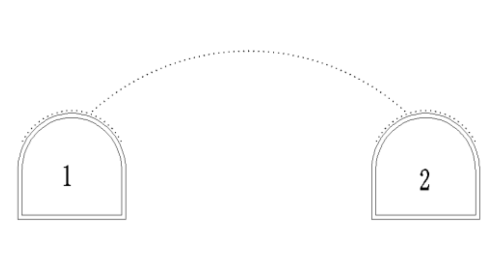
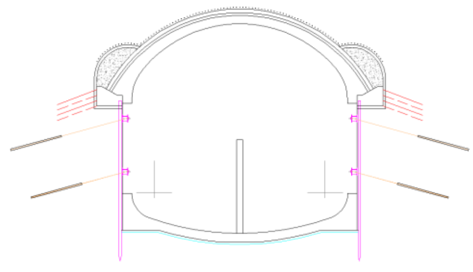
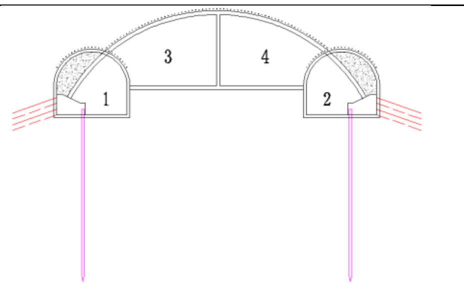
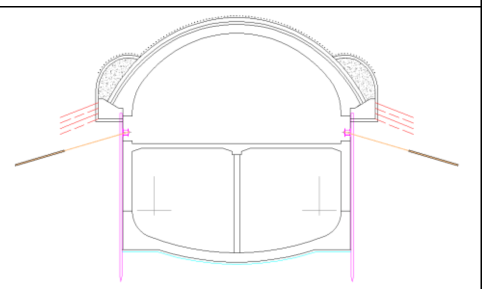
(5) The bottom pad, waterproof layer, structural bottom plate and part of the side wall waterproof layer, two lining structure and platform layer structure column in turn.

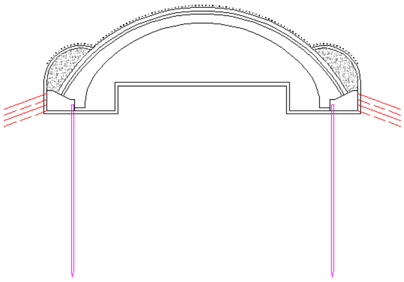
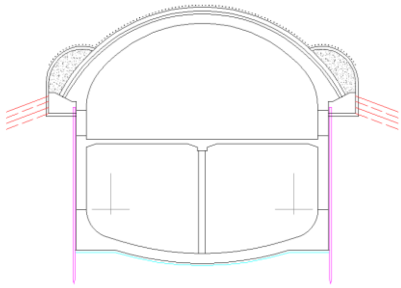
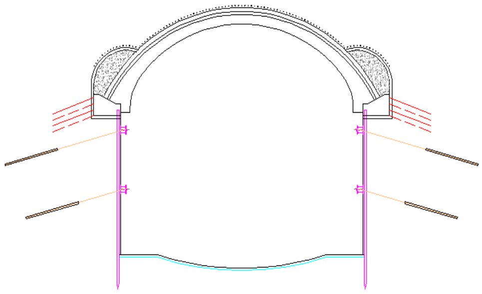
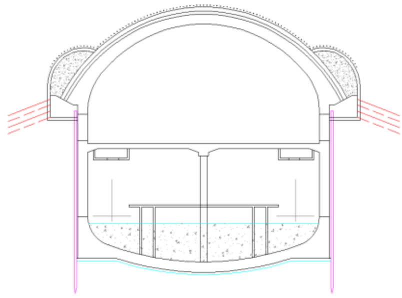
(6) Remove the second prestressed anchor cable in sections. The waterproof layer of the side wall of the station structure and the two lining structure, and the middle plate of the station structure.

(7) Remove the first prestressed anchor cable in sections. The waterproof layer of the side wall of the station structure and the two lining structure are applied.

(8) Backfill the internal structure of the station and the plain concrete under the track surface.

Table 2.1 Construction procedure of arch cover method

Step	Schematic diagram	Step	Schematic diagram
1		5	
2		6	

3		7	
4		8	

2.2.2. The content of construction management of metro station with arch cover method

According to the construction step sequence of subway station with arch cover method introduced in the last section, it can be seen that the construction step sequence of arch cover method is very complex, which means that there are many risks in the construction. The outer primary support and the middle partition wall bear the compressive stress in the construction process. In the construction process, these two parts should be monitored and analyzed in real time to observe the stress changes in the whole step sequence. Finally, the support parameters of the dangerous parts should be studied and analyzed. Therefore, the construction management of the arch cover subway station is mainly divided into the following aspects:

(1) Automated monitoring of the arch cover and high side wall of the arch cover subway station is carried out, and real-time analysis and management of the monitoring data are carried out.

(2) Identifying and summarizing the risks in the whole construction process of the arch cover subway station, establishing the risk hierarchy index system, and then evaluating these risks and developing risk countermeasures.

(3) Design the parameter optimization model of subway station with arch cover method, optimize the construction parameters of the middle and high side wall and main guide tunnel of the station, and form a new support scheme.

2.3. System development ideas

2.3.1. System development process

Generally speaking, from the date the software is conceived, after the software is successfully developed and put into use, until the final decision is made to stop using it and be replaced by another software, it is considered a life cycle of the software[40]. Rolling natural period formula is shown as below:

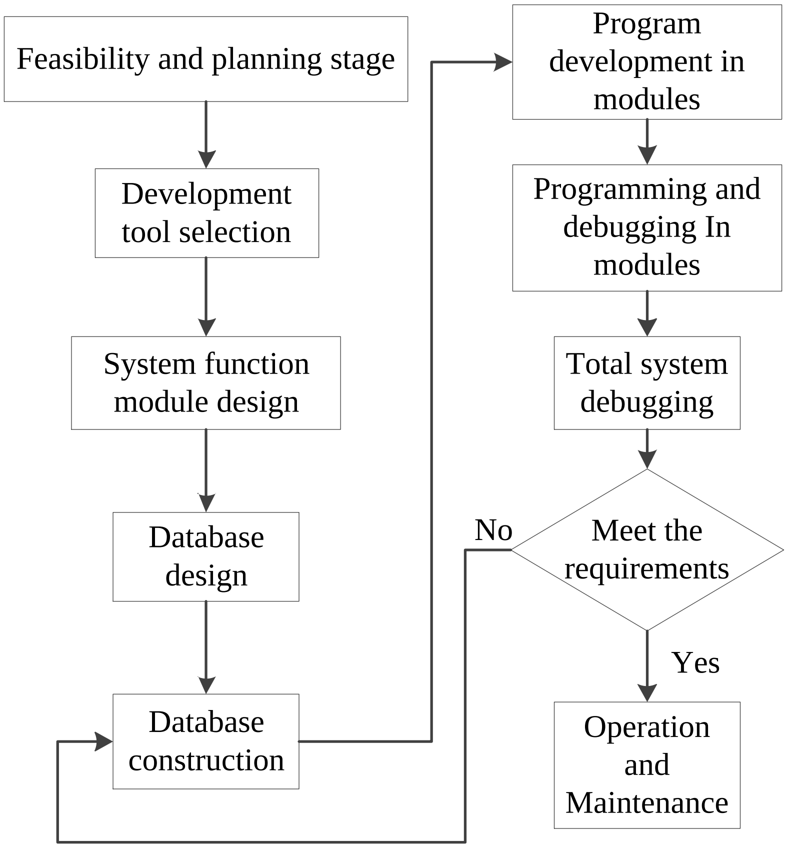


Figure 2.1 Flow chart of software system development

This paper divides the life cycle of the arch cover method subway station information construction management analysis system into six stages: feasibility and planning research, development tool selection, functional design realization, testing, operation and maintenance. In summary, the system development process designed in this article is shown in Figure 2.1. After the completion of the system development, the test application of the Qingniwa Bridge Station Project of Dalian Metro Line 5 is expected to achieve good results.

2.3.2. System development tool selection

The development of the arch cover method subway station information construction management analysis system is based on Microsoft Visual Studio 2010. The system chooses to use the MFC form program as the development environment, and uses the C++ language to carry out the secondary development of the 3D digital earth system based on OSG and osgEarth.

1. System development language

The information-based construction management analysis system and related expansion of the arch cover method subway station developed in this paper select the MFC visual form application development environment and the C++ development language.

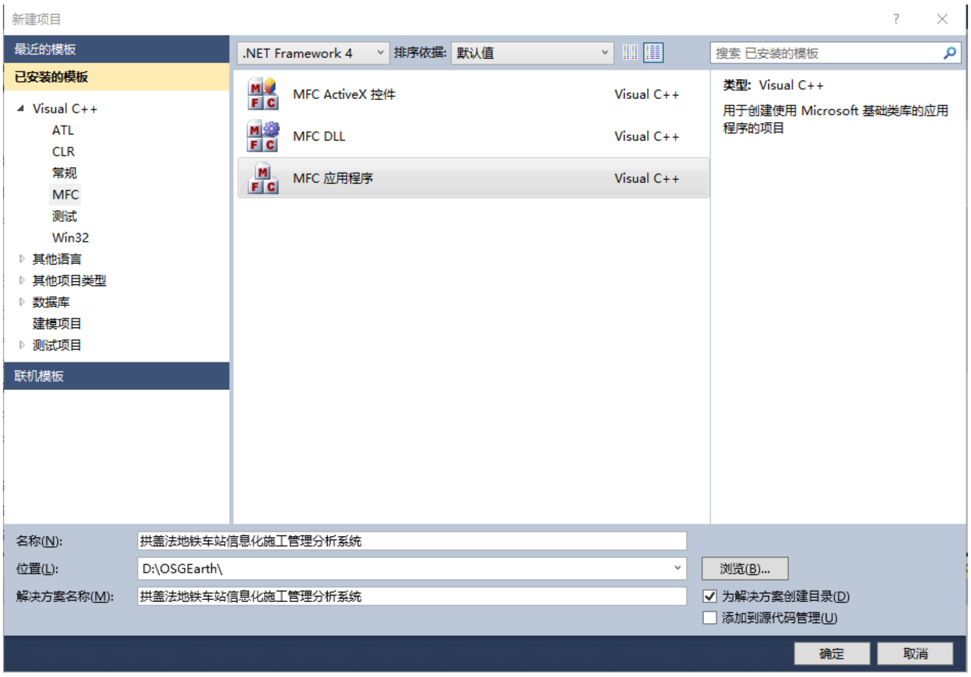


Figure 2.2 Create a new MFC application based on C++ type

C++ is a superset of the C language, maintaining the simplicity and efficiency of the C language, and the C++ compilation system can check for more syntax errors. Therefore, C++ is more secure than the C language. At the same time, C++ is compatible with the C language. Most C language programs can run in the C++ environment without modification. Many library functions written in C language can be used in C++ programs. It can be seen that C++ programs are in many ways. Compared with the C language, it has been improved, making it more suitable for the development of large and medium-sized system software and applications.

2、Database

The data in the system mainly includes geographic information high-definition data and automatic monitoring data. The geographic information data is read and managed by OSG and

OSGEarth rendering engines, while the automatic monitoring data needs to be stored in the database.

SQL (Structured Query Language) is a language for manipulating relational databases. SQL describes the contents of an operation by combining keywords, table names, column names, and so on into a single statement. Keyword refers to English words whose meanings or usage methods have been defined in advance, and there are keywords with various meanings such as "query this table" or "reference this table". SQL statements can be divided into DLL (Data Definition Language), DML (Data Manipulation Language) and DCL (Data Control Language) according to the different types of instructions given by RDBMS. SQL Sever 2008R2 is selected for use in this paper by comparing different versions of SQL databases.

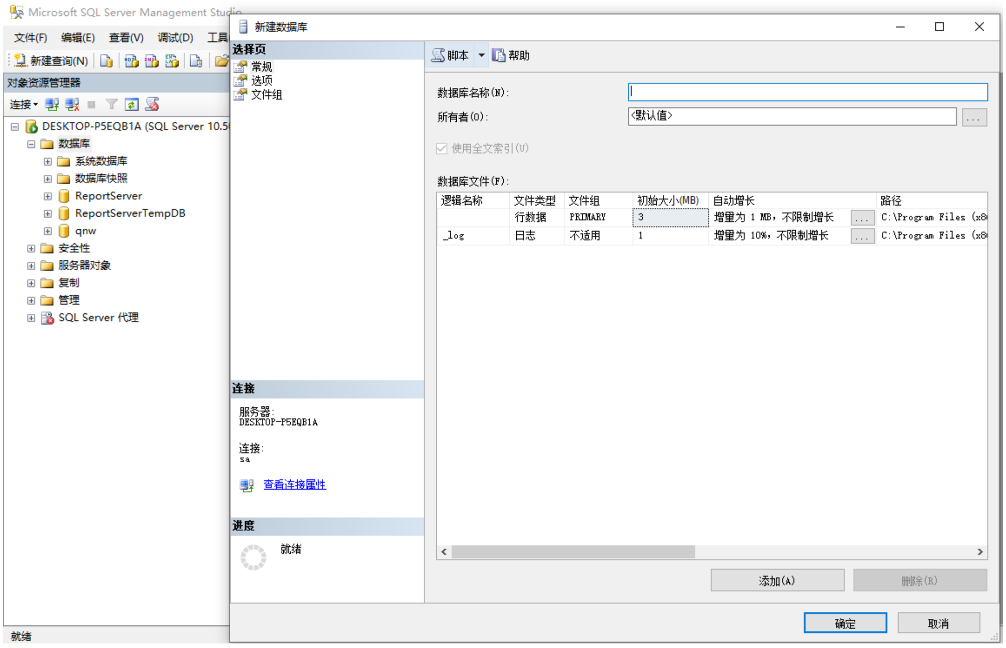


Figure 2.3 Create a new database in SQL Server

3、3D rendering engine

OpenSceneGraph (OSG)[41] is a high-level programmable programming interface (API) for 3D computer graphics development. OSG also has the ability to load cross-platform and 3D data files, such as Earth files. In addition, OSG provides 3D developers with functional interfaces that support the C++ language, including 2D and 3D data file loading, textured font support, level of detail control, multi-threaded data paging, and more.

OSGEarth is a real-time terrain model loading and rendering tool developed based on OSG. OSGERATH can directly read the server side data on the network, and real-time processing and display. It supports WMS, WCS, TMS and other map data servers. It can also connect with Google, Yahoo, Bing and other electronic map servers and obtain data. It can also achieve offline rendering of geographic information data by reading TXT files created by Earth language.

4、Numerical calculation software and intelligent optimization algorithm

The content of the system management in this paper includes the optimization of construction parameters in the arch method subway station, and the optimization process needs to be calculated by intelligent optimization algorithm, so this paper chooses $FLAC^{3D}$ finite difference software as the calculation tool. FISH language is an embedded programming language, which can not only be embedded in the command stream file to work. You can also apply any command from $FLAC^{3D}$ itself. Based on the particle swarm optimization algorithm written in FISH language to use, the system through the txt file written in FISH language to read, modify and call to realize the construction parameter optimization calculation.

2.3.3. System functional design

The whole system mainly includes four parts: monitoring information management module, multi-factor fuzzy evaluation module, construction parameter optimization module and related extension module of arch method subway station. The monitoring information management module contains the monitoring data of various automatic instruments and integrates them into the database of the system for querying and editing. The multi-factor fuzzy evaluation module of construction risk analysis is mainly used to identify and analyze and evaluate the risks in the construction of subway station with arch cover method. The construction parameter optimization system is designed to optimize the construction parameters of the high side wall and the main guide hole in the construction of the subway station with the arch cover method. The extension module is related to the application of actual subway station engineering, such as the optimization of the transportation path of construction mound, the visualization of subway station model, etc. The functional block diagram of the information construction integrated management analysis system is shown in Figure 2.4.

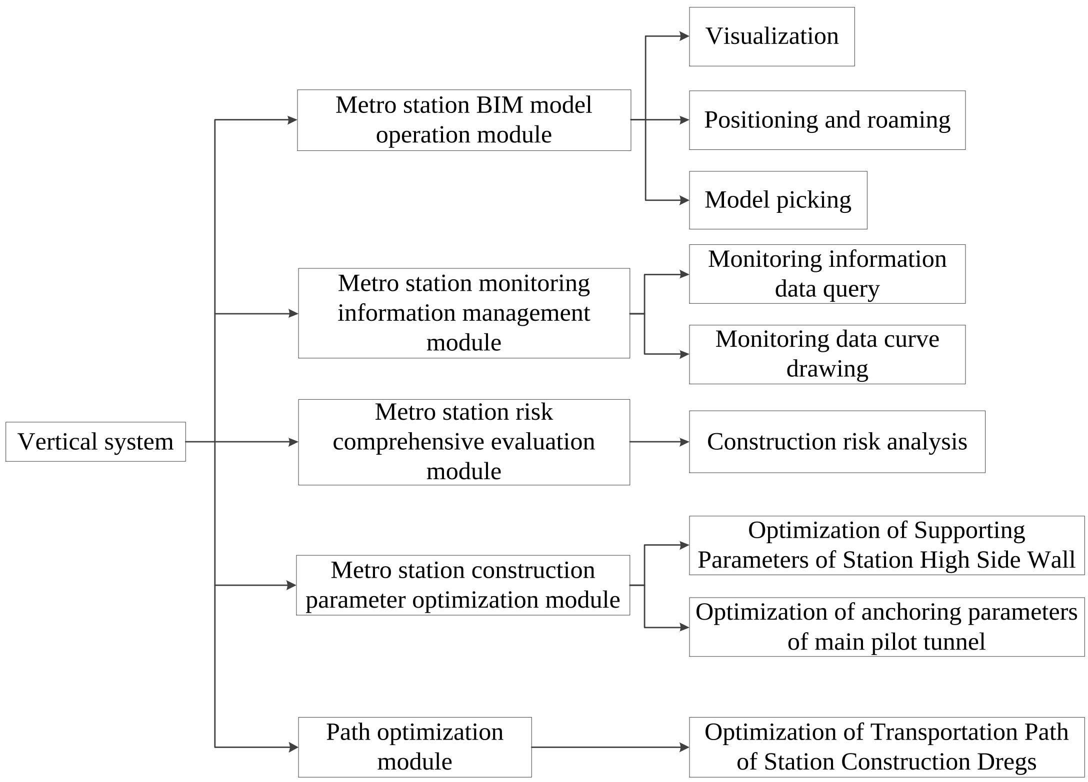


Figure 2.4 Functional block diagram of information construction management analysis system

The function design of the informationized construction management analysis system of the arched metro station developed in this paper mainly includes the following aspects:

1. Automatic monitoring information management technology of arch cover subway station. The data collected by the automatic instruments installed in the subway station project are stored through SQL database and integrated with the system to realize the management and analysis of the automatic monitoring data.

2. Multi factor risk assessment technology of subway station with arch cover method. The risk hierarchy index system of subway station is established by analytic hierarchy process, the weight value of each risk factor is calculated, and experts are invited to score these risk factors. Finally, the risk of arch cover subway station is comprehensively evaluated.

3. Construction parameter optimization technology of subway station with arch cover method. This function module uses the external artificial intelligence algorithm to optimize the construction parameters of the established subway station optimization model, and forms a new support scheme for engineering reference.

4. Visualization of subway station with arch cover method and optimization technology of guide tunnel path. The visualization of the subway station model is realized by combining the positioning and roaming functions of GIS, and the path optimization algorithm is integrated into the system to

optimize the dregs transportation path in the subway station.

2.4. Key technology of system development

2.4.1. Automated monitoring technology

In the subway station engineering, the most important thing to carry out the project normally is the safety construction as the premise, but the engineering construction has a great impact on the near structure. If the surrounding rock and supporting structure in the construction of subway station are monitored only by manual measurement, it will inevitably cost a lot of manpower and material resources, and it is impossible to ensure that the monitoring results can accurately reflect the actual changes of rock mass. Especially for the special geological area in the cross section of the subway and important station monitoring, due to the manual monitoring of low frequency, less measurement content, it is difficult to provide engineering required large amounts of information, and automatic monitoring can effectively solve the above problem, therefore the pluralistic information automatic monitoring technology will be more scientific and reasonable way of monitoring, will also be a subway station monitoring method is the development direction in the future.

In subway station engineering, the automatic monitoring method has the following advantages over the traditional manual monitoring:

(1) It has a high data acquisition frequency, and the monitoring data acquisition frequency can be adjusted in real time by sending the protocol to the automatic acquisition equipment.

(2) It has a high data accuracy, automatic monitoring avoids accidental errors of manual monitoring to a certain extent, and effectively ensures the accuracy of data collection.

(3) It has real-time monitoring, automatic monitoring can be at any time and any place through the system setting to monitor the site data, to avoid the impact of the site construction environment can not be real-time monitoring of the project.

(4) It is used for station safety monitoring in operation stage. When the subway station enters the operation stage, because the structure of the station has been formed, it is difficult to monitor the internal structure by manual monitoring, while the automatic monitoring equipment can still monitor the work in the station and will not be affected by it.

2.4.2. Database Technology

Database technology is a soft subject that studies the structure, storage, design, management and application of database. Database system is essentially a system that uses computer to store information. The database management system is located between the user and the operating system of a layer of data management software, the basic goal is to provide a convenient, effective access to the database information environment. A database can be viewed as a container for collecting computer data on which system users can perform a series of operations. The main purpose of designing database system is to facilitate the management of large amounts of data information.

As the subway station project will produce a large amount of construction information every day, with the rapid increase in the number of data, the database technology reflects a huge advantage, the construction staff gradually began to edit the data archive storage, now through the computer database to manage and store the construction information.

In the system platform developed in this paper, there is a large amount of monitoring data which needs to be stored and managed by database. When selecting the client database, it is considered that the embedded database does not need an independent running engine, and the relevant operation of data can be realized directly by calling the corresponding API by the program. By comparison, it is found that SQL Sever 2008R2 database can build and manage data applications with high availability and high performance. Its engine provides more secure and reliable storage functions for relational data and structured data. Therefore, SQL Sever 2008R2 database is finally chosen on the server side.

The key code to realize the database connection function is as follows:

```
bool SqlServerDb::ConnectDb()
{
    HRESULT hr = m_sqlSp.CreateInstance(_uuidof(Connection));
    if(FAILED(hr))
    {
        return false;
    }
    _bstr_tstrConnect="Provider=SQLOLEDB;Server=127.0.0.1,1433;Database=skl;uid=sa;pwd=lfy
yc888;";
    m_sqlSp->Open(strConnect,"","",adModeUnknown);
    if(FAILED(m_pRecordset.CreateInstance( _uuidof( Recordset ))))
    {
        return false;
    }
    return true;
}
```

2.4.3. View location and roaming technology

Positioning effect is a common function in GIS software. Global positioning system is a function that allows users to input coordinate information to make the view point of the system automatically focus to the designated area. The coordinate information generally includes the longitude, latitude, height and Angle of view of the coordinate. OSG provides setViewpoint function to realize the positioning function.

In order to realize the real-time identification of the coordinate information input by users, the system extracts the longitude and latitude coordinates, height information and visual Angle input by users, so as to change the main view point of the system to the corresponding coordinate point position, so as to achieve the positioning effect.

Specific implementation methods are as follows:

```
CDigitalEarthApp* pApp = (CDigitalEarthApp*)AfxGetApp();
CMainFrame* pWnd = (CMainFrame*)pApp->GetMainWnd();
{ CMFCRibbonEdit*edit=dynamic_cast<CMFCRibbonEdit*>(pWnd->m_wndRibbonBar.FindByID(I
D_LON));
if(edit)
        {
            CString str = edit->GetEditText();
            std::string strTemp(str.GetBuffer());
                double opt = std::atof(strTemp.c_str());
                if((180<opt) || (opt<-180))
                {
                MessageBox("Longitude must be between (-180,180)", "error", MB_OK|MB_
ICONERROR);
                str.Format("%f", flylon);
                edit->SetEditText(str);
                return;
                }
                else
                {
                    flylon = opt;
                }
        }
    }
    {
    CMFCRibbonEdit*edit=dynamic_cast<CMFCRibbonEdit*>(pWnd->m_wndRibbonBar.FindByI
D(ID_LAT));
    if(edit)
    {
            CString str = edit->GetEditText();
            std::string strTemp(str.GetBuffer());
            double opt = std::atof(strTemp.c_str());
            if((90<opt) || (opt<-90))
        {
            MessageBox("Latitude must be between (-90,90)", "error",
MB_OK|MB_ICONERROR);
                str.Format("%f", flylat);
                edit->SetEditText(str);
                return;
            }
            else
            {
                flylat = opt;
            }
        }
    }
```

```
    {
mOSG->FlyTo(flylon, flylat, flyhei);
```

View roaming[42] is a practical function that allows the system's view point to move along the specified path. The user-defined path is defined by using two quantities: coordinates and time. The coordinate refers to each key point in the path, which is corresponding by setting the coordinate values of longitude and latitude of the key points. The roaming time refers to the time taken from the current key point to the next key point. The longer the time is, the slower the movement speed of the view point is.

Virtual roaming subway station is a very important function in this system, users can through the first-person perspective into the internal view, in the process of check the users according to their own needs can convert the viewing Angle, the function implementation principle is by setting the system parameters such as viewpoint of latitude and longitude coordinates, pitching Angle and speed, realize the roaming of virtual station.

The essence of realizing the view roaming function is to change the position of the main view point of the digital earth built by the system. By means of matrix transformation, the coordinate system of the digital earth can be converted to the longitude and latitude coordinate system. In setting path roaming, roaming first need to set some path to the key point to planning the path, and record the key point of latitude and longitude information, and then the key point of latitude and longitude information into a 3D world coordinate system (x, y, z) coordinates that can determine the position of the point of view of change, then calculate the corresponding transformation matrix, so as to realize the specified path.

OSG provides AnimationPath class to realize path roaming function, which includes insert, getMatrix, setLoopMode, getPeriod and other functional functions. Its specific functions are shown in Table 2.2 below.

Table 2.2 The Correlated function of the AnimationPath class

Function name	Function
insert	Insert key points, including the time, position, and orientation of view roaming
getMatrix	The matrix defined in the roaming path is obtained, from which the relevant parameters of the view point can be calculated in reverse
setLoopMode	Set the loop mode and specify that the roaming path remains in the loop state
getPeriod	Get the time range for the roaming demo

Taking the model of Qingniwaqiao Metro Station of Dalian Metro Line 5 as an example, the location and height of key points on the roaming path and the roaming time between key points are pre-set before roaming to form a complete roaming path, and the view controller will conduct roaming according to this path. The code for setting key points on the path is as follows:

```
osg::ref_ptr<osg::Vec4Array> vaTemp = new osg::Vec4Array;
vaTemp->push_back(osg::Vec4(139.792575, 35.669596, 1, 10.0));
vaTemp->push_back(osg::Vec4(139.792010, 35.669796, 1, 10.0));
vaTemp->push_back(osg::Vec4(139.793340, 35.670864, 1, 10.0));
vaTemp->push_back(osg::Vec4(139.795020, 35.670138, 1, 10.0));
vaTemp->push_back(osg::Vec4(139.795979, 35.671884, 1, 10.0));
vaTemp->push_back(osg::Vec4(139.794572, 35.672393, 1, 10.0));
```

In the process of scene roaming, because of the influence of the view controller perspective will continue to change, for the convenience of the user roaming direction, while roaming also realize the function of ones, add a pointer at the lower left corner of the program interface can be real-time pointing to the N side, in order to determine the southeast to northwest, and would change with the rotation of the map.

To ensure that the needle will not be affected by other events and that the dial will rotate as the map view changes, we used the HUD in OSG to achieve this. The HUD is essentially a two-dimensional camera that does not accept mouse dragging and other events. It is rendered after all scenes are rendered, and always remains on top of the scene. The needle is divided into dial and pointer two parts. Create geometry for these two parts and associate them to a specific rendering element. Specify the drawing order of the geometry through the rendering element to ensure that the needle is drawn last. In order to make the pointing needle point to the north correctly, the system sets up the real-time acquisition of the direction parameters of the view operator, and calculates the rotation Angle of the dial and pointer according to the direction parameters. The specific implementation method is as follows:

```
_plate = createCompressPart("D:\\GIS\\DigitalEarth\\label\\compass_plate.PNG", 1.5, -1.0);
compass = new osg::Camera;
compass->setViewport(0, 0, 128, 128);
compass->setProjectionMatrix(osg::Matrixd::ortho(-1.5, 1.5, -1.5, 1.5, -10, 10));
compass->setRenderOrder(osg::Camera::POST_RENDER);
compass->setClearMask(GL_DEPTH_BUFFER_BIT);
compass->setAllowEventFocus(false);
compass->setReferenceFrame(osg::Transform::ABSOLUTE_RF);
compass->getOrCreateStateSet()->setMode(GL_LIGHTING, osg::StateAttribute::OFF);
compass->getOrCreateStateSet()->setMode(GL_BLEND, osg::StateAttribute::ON);
compass->addChild(_plate);
mRoot->addChild(compass);
_needle = createCompressPart("D:\\GIS\\DigitalEarth\\label\\compass_needle.PNG", 1.5, -1.0);
eh = new CEventHandler;
mViewer->addEventHandler(eh);
eh->_plate = _plate;
```

2.4.4. Model reading and picking function

To read and pick up the subway station model in the system, you first need to establish a subway station model file that can be recognized by the OSG platform. The types of models that can be recognized on the 3D digital earth built on the OSG platform are osg, ive, OSGB, etc. In this paper, the OSGB model of oblique photography is selected for the model display of the station.

At present, most OSGB models use software such as Smart3D, Skyline, SuperMap, etc., after a certain processing process, and generate high-resolution real-life 3D models with ultra-high-density point clouds generated based on real image operations[43], while for subway stations The model is restricted by many factors such as the environment, and it is difficult to obtain image data. To solve this problem, this article explores the conversion method between the BIM subway station model and the OSG platform reading model from the perspective of model data conversion, and initially realizes the reading and picking function of the BIM model on the OSG platform. The specific ideas are as follows:

(1) The BIM model of the arched subway station is established through the Revit modeling platform, and the information of the subway station model is constructed by using BIM, and then the model is exported into an image file in the format of FPX by Revit platform.

(2) Open the above FPX file in 3DMAX software and convert it into a 3D model of skew photography OSGB type using OSGexp plug-in, which can be recognized by OSG platform.

(3) The model is placed on the digital earth through the model reading function in the OSG platform.

Through the above steps, the function of BIM model reading and display on OSG platform can be achieved. This method successfully solves the difficulty of image data collection of subway station, and the modeling efficiency is also greatly improved by establishing the model through Revit software. The conversion method flow chart of BIM subway station model and OSG platform reading model is shown in Figure 2.5.

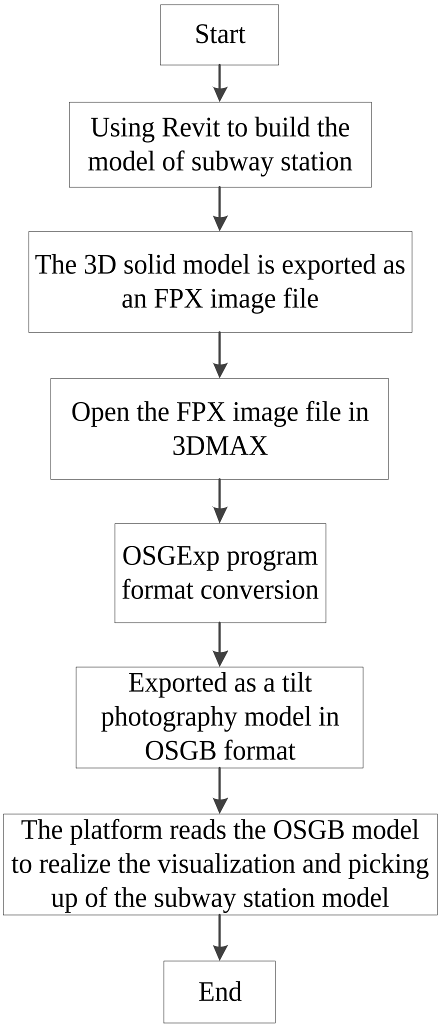


Figure 2.5 Flow chart of conversion method between BIM model and OSG platform read model

Pick up the model, that is, the user can select the model in the specified scene by clicking the mouse. In order to realize the above pickup function, it is necessary to record the position information of the mouse click first, so as to identify the method of the model that intersects the ray emitted by the mouse and judge the pickup object. Therefore, to realize the model pickup, the most critical problem is the intersection operation of ray and model. This paper uses the ComputeIntersection class in OSG Viewer to calculate the intersection point between the mouse's rays and the model in the scene.

The main classes involved in picking up the model are the Intersector class, the IntersectionVisitor class, and the LineSegmentIntersector class. The results of the intersecting test are recorded in the OSG::NodePath object, which records the node route of a certain level from the root node to the leaf node in the scene, and the node that intersects first can be obtained.

The relevant code is as follows:

```
bool CPickHandler::handle(const osgGA::GUIEventAdapter& ea,
```

```
osgGA::GUIActionAdapter& aa)
{
    switch (ea.getEventType())
    {
        case(osgGA::GUIEventAdapter::RELEASE):
        {
            If(ea.getButton()== osgGA::GUIEventAdapter::LEFT_MOUSE_BUTTON)
            {
                pick(ea.getX(), ea.getY());
            }
            return true;
        }
    }
    return false;
}
std::string DoubleToStringByStringStream(float value)
{
    std::ostringstream stream;
    stream << value;
    return stream.str();
}
void CPickHandler::pick(float fX, float fY)
{
    osgUtil::LineSegmentIntersector::Intersections intersections;
    if (m_pViewer->computeIntersections(fX, fY, intersections))
    {
        auto itr = intersections.begin();
        bool e = true;
        while(itr != intersections.end() && e)
        {
            if (!itr->nodePath.empty())
            {
              const osg::NodePath& np = itr->nodePath;
              int i = np.size() - 1;
              bool entry = true;
              while(i >= 0 && entry)
              {
                osg::ref_ptr<osg::Node> node = dynamic_cast<osg::Node *>(np[i]);
                if (NULL != node && node->getName().compare("model_name") == 0)
                    {
                    }
                    i -= 1;
              }
            }
            ++itr;
        }
    }
}
```

When picking up the model, an event can be triggered when different locations of the model are selected. The event can be customized to view relevant information of the engineering database or call function modules to realize the model interaction function in 3D scenes.

2.5. *Chapter summary*

This chapter first introduces the construction process of the arch-cover method subway station, combines the characteristics of the arch-cover method construction technology to elicit the content of construction management and forms the idea of system development, and summarizes the design of the main functional module that needs to be developed for the subway station monitoring information Management module, subway station risk comprehensive evaluation module, and arch cover method subway station construction parameter optimization module, and introduced the key technologies adopted by the system, so that the arch cover method subway station information construction management analysis system developed in this paper has a certain target Sexual effect.

3. Automatic collection and management technology of construction information of arch covered stations

3.1. *introduction*

With the development and integration of database and automatic monitoring and other related technologies, the realization of metro station construction information is the development trend of the future construction. However, the information in the existing metro station construction monitoring and management is mostly transmitted by documents, forms, conferences and other communication methods. The whole cycle of information collection, arrangement, retrieval and analysis takes too long, and the transmission efficiency is also very low. As for the construction of the arch method subway station, due to the complexity of the construction environment and construction methods, it is more necessary to carry out real-time monitoring, analysis and management of the information generated in the construction. Therefore, it is very necessary to develop the monitoring information management module of the arch method subway station.

3.2. Construction monitoring hardware layout scheme of arch roof station

3.2.1. The composition of system hardware

(1) Earth pressure cell

Earth pressure cell is a kind of steel string sensor for measuring earth pressure. It is suitable for measuring the internal stress of soil under various conditions. It is often used for monitoring the earth pressure of tunnel, roadbed, anti-slide pile, retaining wall and other engineering. Long-term monitoring and automatic measurement can be carried out. On-site installation to earth pressure box diameter first round steel bar, the length of the configuration in the steel claw central welding on the back of a long bar, aims and steel arch frame welding together convenient fixed earth pressure box, and then put the earth pressure box at the front of the steel claw, earth pressure box by side close to the surrounding rock, long after the reinforced steel arch frame welded together, achieve the goal of fixed earth pressure box, The earth pressure chamber and its installation pictures are shown in Fig. 3.1.

Figure 3.1 Images of earth pressure chamber and its installation

(2) Rebar meter

Use a rebar meter to monitor the stress of the steel arch. The rebar meter is mainly used to measure the stress of the steel bar or the anchor rod in the structure. In the construction, the installation method of welding at both ends is adopted, which is buried in the reinforced concrete structure, and the stress of the steel bar is measured after the concrete has solidified. When installing, first prepare a towel and soak it in cold water for later use. Place the rebar gauge close to the side of the steel arch as shown in the right picture of Figure 8. The terminal of the rebar gauge is located on the upper side of the rebar, and then use a towel soaked in cold water to wrap the middle protruding part of the rebar gauge and the rebar together, Play the role of protecting the rebar gauge, so as not to damage the rebar gauge due to high temperature, and then use the welding rod to weld the two ends of the rebar gauge to the steel bar. After welding, the towel can be removed after about 10 minutes. The installation picture is shown in Figure 3.2.

Figure 3.2 Images of reinforcement meter and its installation

(3) Embedded strain gauge

Use a strain gauge to monitor the strain value of the middle wall. Embedded concrete strain gauges are suitable for safety monitoring in bridges, tunnels, dams, underground building construction, test piles and foundation pit excavation. When installing, first place the strain gauge on the middle part of the middle partition wall as shown in the right picture, close to the steel bar, and fasten the two sides of the strain gauge with a wire tie, and then wrap the strain gauge with cellophane tape a few times. In order to achieve the purpose of further fixing, then pour the concrete, the strain gauge and its installation picture are shown in Figure 3.3.

Figure 3.3 Images of strain gauge and its installation

(4) Laser rangefinder

The laser range finder is used to monitor the headroom convergence value of the high side wall of the station, which is an instrument that uses pulsed laser beams for distance measurement. In the station displacement measurement, the laser rangefinder is installed from one side wall, and the distance from the laser to the opposite wall for the first time is the initial value of the displacement between the two walls of the station, and each subsequent measurement is compared with the initial value. Is the convergence value of the side wall displacement. When installing the laser rangefinder, you need to pay attention to the intensity of the ambient light. If the light is too strong, astigmatism may occur.

During the on-site installation, due to the complex construction environment of the station, in order to protect the laser rangefinder, a steel box was made according to the size and measuring range of the laser rangefinder, and the laser rangefinder was welded in the box, and finally the steel plate was welded with expansion screws. The box is fixed on the high side wall, and the level of all laser rangefinders should be kept consistent during installation. The line connecting the instrument should also be fixed on the wall, so that it can't be hung naturally to prevent it from being loosened by gravity. The laser rangefinder and its installation picture are shown in Figure 3.4.

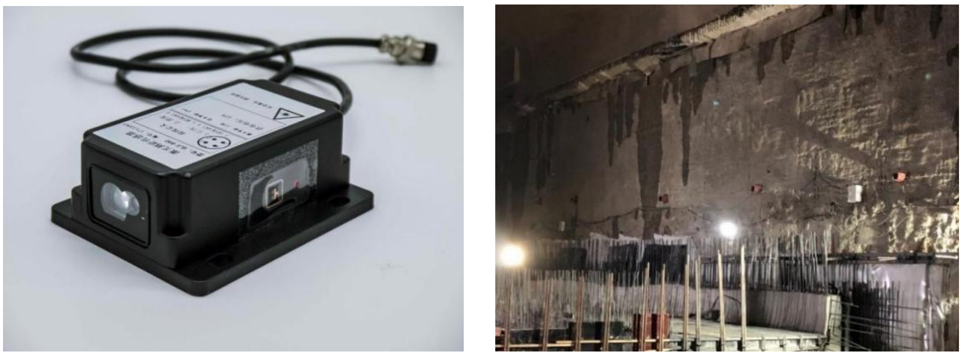


Figure 3.4 Images of laser rangefinder and its installation

(5) Multi-information data collection and transmission system

In the laboratory, the sensors of different models and different frequencies are debugeduntil the normal data transmission can be carried out with the 32-channel vibrating string data acquisition system. The corresponding sensors should be arranged in the monitoring position required on the project site, and the signal cable should be extended along the project boundary and effectively protected to prevent possible damage caused by the construction. Select the appropriate location, arrange the automatic acquisition box, and connect the signal lines of different sensors to the location of the acquisition box at the same time. The data of each sensor is collected in the 32-channel vibrating string data acquisition system inside the acquisition box through the cable, and the data is transmitted to the data transfer transmitting box through the KYL wireless transmission system. The transmitting box receives the data through the KYL system, and uploads the data to the server through the GPRS module to link the signal base station, so as to realize the remote acquisition of automatic monitoring data. At the same time, in order to deal with the situation of on-site power failure caused by human or construction in the subway station, a standby power supply system powered by battery is added to the collection box to ensure the normal operation of the collection system. The on-site installation of automatic collection box and launching box is shown in Figure 3.5.

Figure 3.5 On-site installation drawing of automatic collection box and launch box

3.2.2. *Monitoring point layout plan*

Since the Qingniwa Bridge Station uses the arch cover method, the arch cover is an important part of the subway station support, and its force status directly affects the stability of the structure. Therefore, it is necessary to monitor the intermediate wall and the initial support at the arch cover. This program selects five sections of k8+441, k8+462, k8+483, k8+504, and k8+526 for automatic sensor embedment, as shown in Figure 3.6.

（1） Layout of the monitoring points of the arch section

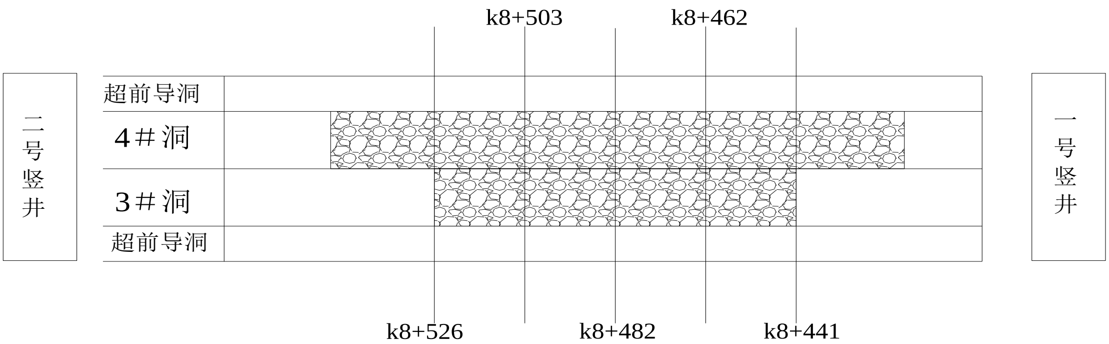


Figure 3.6 Monitoring section distribution map

At the beginning of each monitoring section of a branch set up seven monitoring points, are buried in station center line and center line side around 30 °, 60 ° symmetrical layout and arch foot, at the beginning of the second set five monitoring points, are buried in station center line and center line left and right side of the 45 ° symmetrical layout and arch foot, sensor types mainly include soil pressure box, steel bar meter, embedment strain gauge. Soil pressure box located in the subway station of surrounding rock and early, early and early secondary branch, between reinforcing steel bar meter located on both sides of the arch top and bottom steel, strain gauge is located at the station in the next place, this article selects the typical section of k8 + 441 to decorate display and automatic monitoring data analysis, k8 + 441 section at the beginning of a sensor arrangement as shown in Figure 3.7, The layout of the secondary primary sensor of section k8 +441 is shown in Figure 3.8.

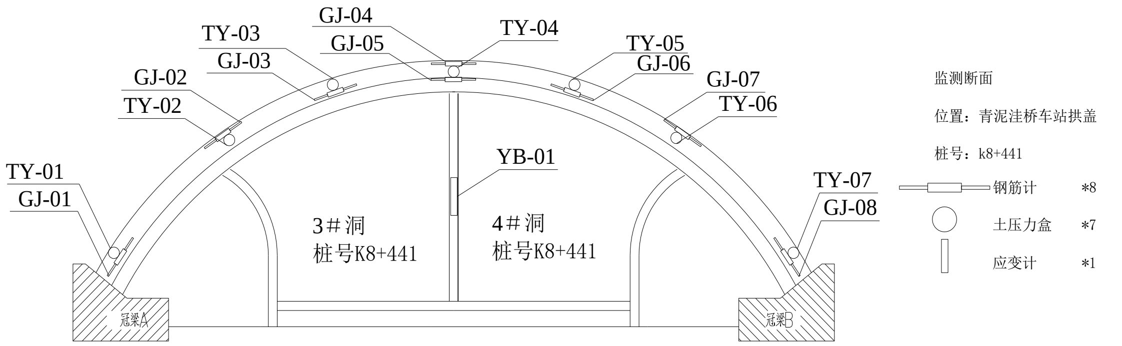


Figure 3.7 Sensor layout drawing for the first primary support at section k8+441

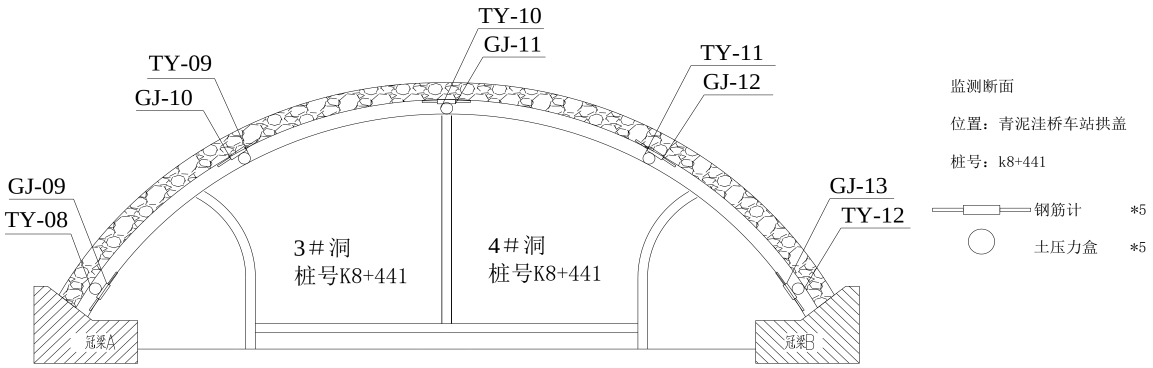


Figure 3.8 Sensor layout drawing for the second primary support of section k8+441

（2） Layout of monitoring points on high side walls

Current green clay hollow bridge station section or infrastructure construction has begun at the station, at this time due to the lower soil excavation, the station of high sidewall location for surrounding rock pressure level will happen to the convergence displacement, with the increase of station excavation length, high sidewall position may change a larger displacement, so the need for real-time monitoring of this place.

In order to ensure the safety of the station construction, laser rangefinder is installed at the high side wall, and the convergence value of the headroom of the high side wall is automatically monitored. Select the station has been in the bottom of excavation section 100 m within the scope of the installation of the laser range finder, instrument installation position for the station high sidewall, design installation height is 5 m, laser range finder is asked to keep the same level, and each horizontal spacing of laser range finder to 10 m, concrete installation plan as shown in Figure 3.9.

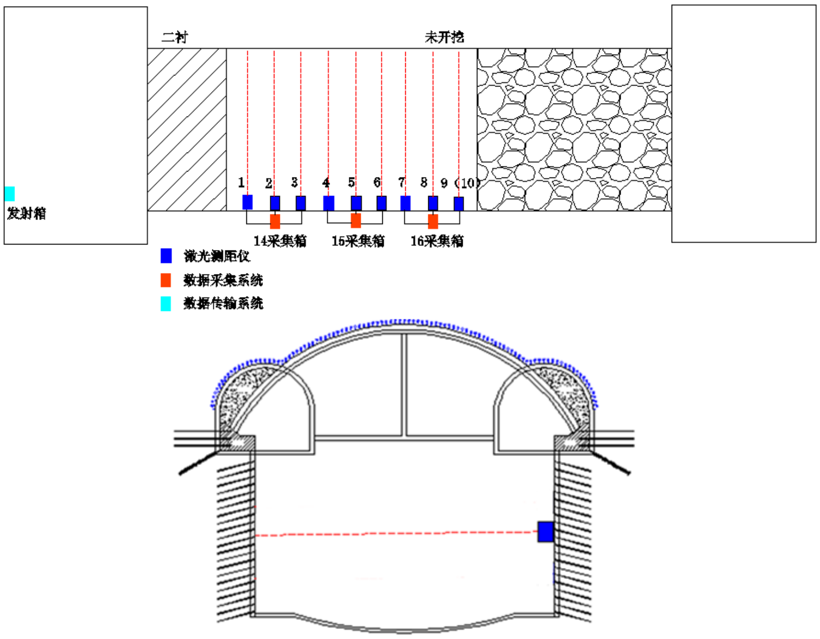


Figure 3.9 Installation plan of laser rangefinder

In the project site need to monitor the location of the corresponding sensor arrangement, the signal cable along the project boundary layout extension and effective protection, this is not allowed to ignore is also a very important work, in order to prevent the construction may cause damage. Soil pressure of the box, steel bar meter, strain gauge, a laser range finder to tidy all the extended line, together with prepared casing wear the line into the casing, casing along the steel arch shelf closely fixed internally with transparent tape and insulating tape, casing, extend to the lateral drift with expansion screws hook should be fixed to the lateral drift, extends to the crown beam. If there is no casing, the wire should be tightly bonded along the back side of the steel bar of the steel arch. Then, the wire and the steel bar should be tied tightly and tightly with insulating tape. Then, the wire should be tightly and firmly wrapped with transparent tape and wound for at least two layers, as shown in Figure 3.10.

Figure 3.10 Site line protection drawing

3.3. *Monitoring information management module*

3.3.1. *Module development*

(1) Transmission of hardware monitoring information

This module adopts automatic monitoring technology. The installed sensor and the multi-information data acquisition and transmission system are used for monitoring information transmission through GRPS, and the monitoring data are transferred from the site to the server for storage. The overall model of data transmission is shown in Figure 3.11.

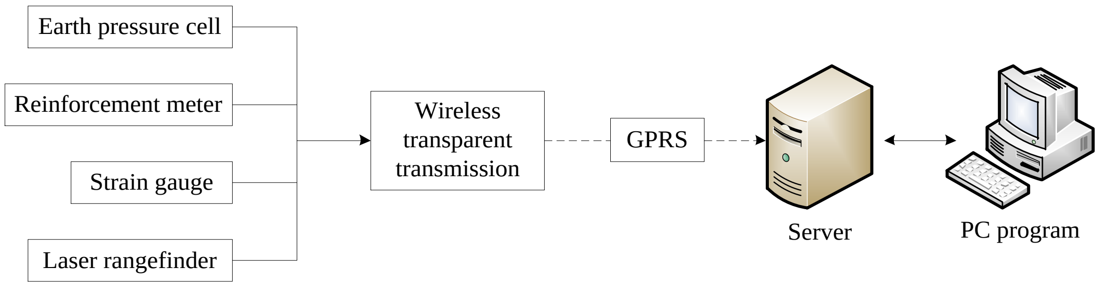


Figure 3.11 Monitoring information transmission model

Because the construction environment of the subway station site is relatively complicated and underground, the transmission signal is poor, and the overall trend of the station excavation construction is not a complete straight line. The transmission signal may sometimes be collected by the automatic collection box due to other obstacles on the transmission path. The data could not be transferred to the server. In order to solve this problem, try to ensure that the information transmission path is unblocked during the installation process, and install a relay module at a location where the transmission may be blocked, which is equivalent to adding a relay station on the information transmission path, and receive the transmission through the relay module. The signal from the module is then transported to the automatic collection box. After practicing this method, the influence of the subway station construction environment on the signal transmission of automatic monitoring can be effectively improved.

(2) Database construction

Data construction for monitoring information of subway station construction is an important part of monitoring information management module. SQL Sever software is used to build the database. The display of SQL Sever database is shown in Figure 3.12. The database stores alarm level, measuring point diagram, over-limit data, sensor information, monitoring data, etc. The monitoring information management module developed in this paper mainly reads the monitoring database in the SQL Sever database[44].

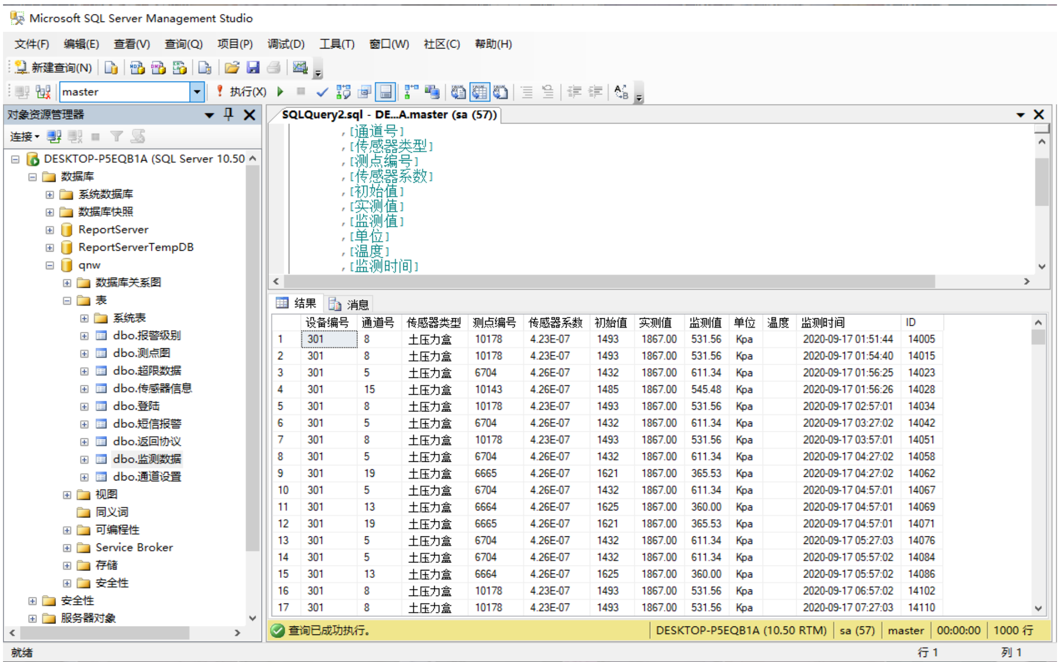


Figure 3.12 SQL Sever database display

The content of monitoring data mainly includes sensor type, sensor coefficient, measurement point number, channel number, monitoring value, etc., as shown in Table 3.1.

Table 3.1 Monitoring information content table

Field name	Field definition
Sensor type	The name of the field automation monitoring sensor
Sensor coefficient	The coefficient used for the system to calculate the sensor monitoring value
Measuring point number	Sensor installation position number
Channel number	The sensor is connected to the channel number in the automated collection box
Initial value	The original value of the sensor factory setting
Measured value	Field measurement value after installing the sensor
Monitoring value	The value of the sensor's corresponding monitoring content
Monitoring time	Time point of sensor monitoring value generation
Unit	The unit of the sensor monitoring value, such as kPa, kN
Temperature	The internal temperature of the sensor at this time

According to the content of the monitoring information, design the logical structure of the monitoring database, and design the corresponding field attributes of each type of monitoring data content. The description of the field attributes of each type of information is shown in Table 3.2.

Table 3.2 Attribute description table of monitoring information field

Field name	Type
SensorType	Txt
SensorCoefficient	Numb
TestNumber	Txt
ChannaleNumber	Numb
StartNum	Numb
RealNum	Numb
ViewNum	Numb
Time	Txt
Uint	Txt
Temper	Txt

(3) Database connectivity

The main function of the monitoring information management module of the arch method subway station is to store, call and query the data of the on-site automatic monitoring, which also means that the module needs to connect and read the monitoring information database built by the system. This paper selects the embedded database SQLite for database storage, and connects it with the MFC window program through the ADO (ActiveX Data Objects) object to realize the creation or modification of tables, query, check the database and access to external Data sources. The Data visualization process of this module is shown in Figure 3.13.

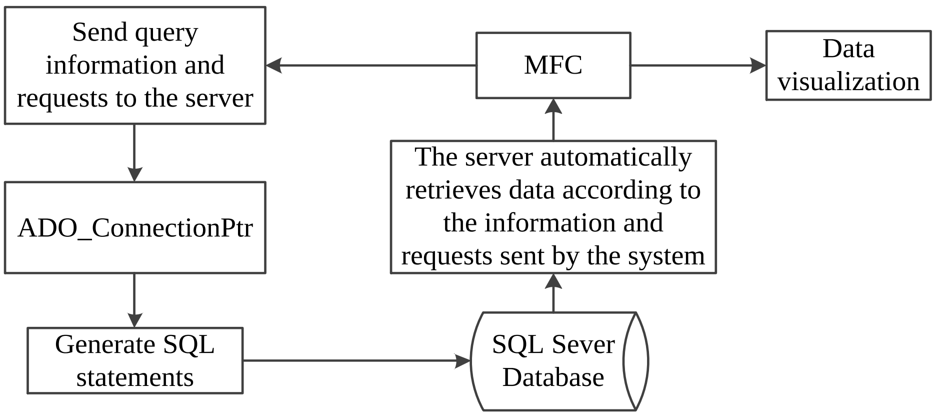


Figure 3.13 Data visualization flow chart

3.3.2. Module function display

(1) Monitoring data query function

Open the monitoring platform, and the system will automatically connect to the monitoring database in SQL Sever. In order to allow users to accurately view the specified information, this function sets up a conditional query window for the directional view of the monitoring data. The conditional query includes the number of the measuring point, the type of the sensor, and the monitoring date. The queryable data includes the device number, channel number, sensor coefficient, initial value of the sensor, measured value of the sensor, monitored value, unit, and the specific time when the data was detected. The monitoring information is presented in the form of reports, as shown in Figure 3.14.

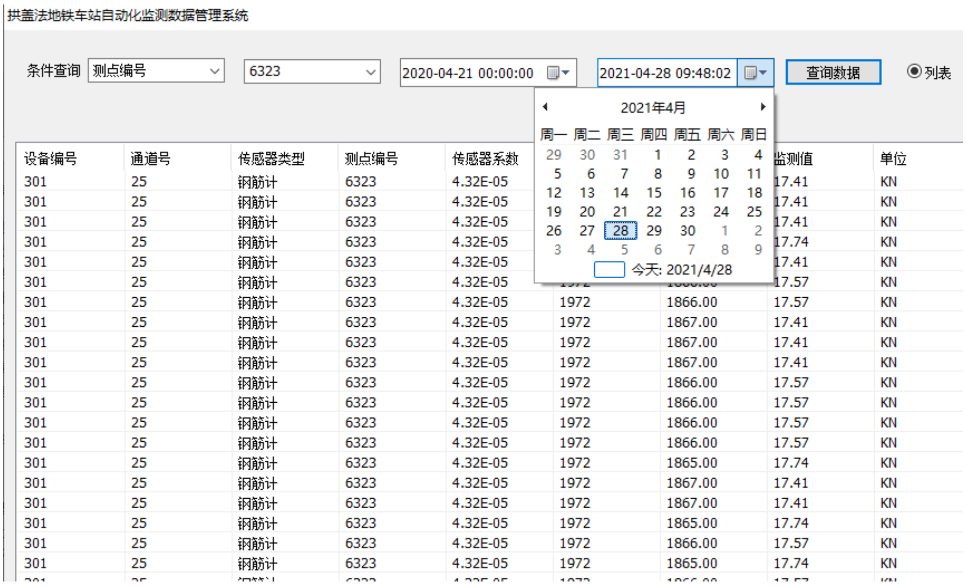


Figure 3.14 Conditional query of monitoring data

(2) Monitoring data curve drawing function

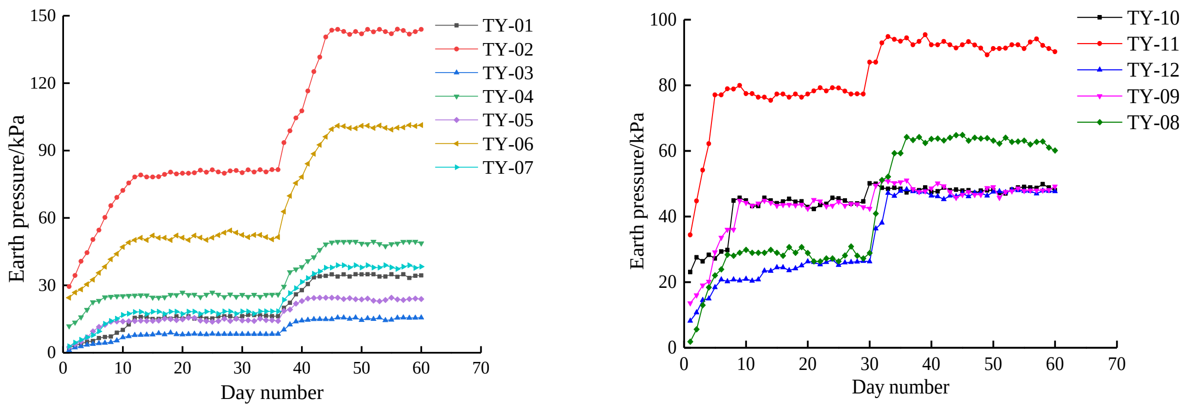
In order to facilitate the user to view the change trend of automatic monitoring data, the module set the curve plotting function of monitoring data, the same function by directional view query conditions, can be realized to a specified sensor type or the number of measuring points in a certain period of monitoring data curve drawing, at the same time module can also set the graph of longitudinal axis range, It is convenient for users to control the range of broken line change and then analyze the monitoring data. The previous data management needs to extract and generate the Exel form from the original database, and then draw the curve through the third party software. However, the automatic acquisition management module developed by this system can read and draw directly, which effectively improves the efficiency of data query. The changes of monitoring data are viewed in the form of broken line chart, as shown in Figure 3.15.

Figure 3.15 Monitoring data polyline drawing interface

3.4. Analysis of monitoring data of typical sections in arch covering stations

3.4.1. Analysis of the earth pressure value of the station

By monitoring information management module of data query function, extraction and analysis was carried out on the field monitoring data, this article selects the typical section of k8+ 441 automatic monitoring data analysis, in order to more intuitive display sensor data change process, the following chart analysis in the process, on April 26 as the time to begin namely 0 days analysis.

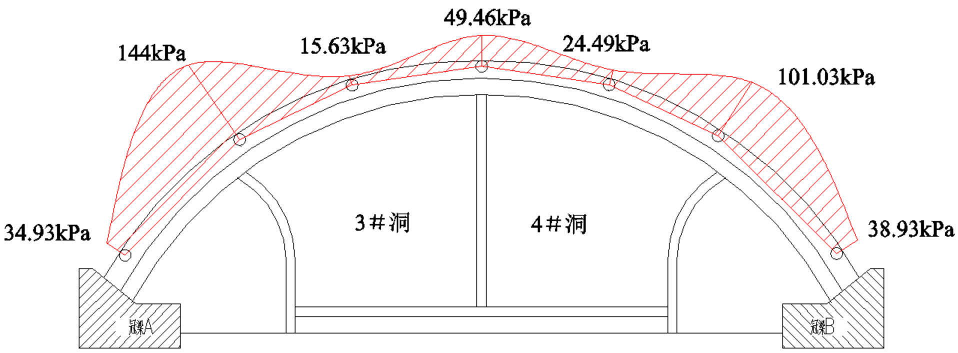


（a） First primary earth pressure monitoring （b） Second primary earth pressure monitoring

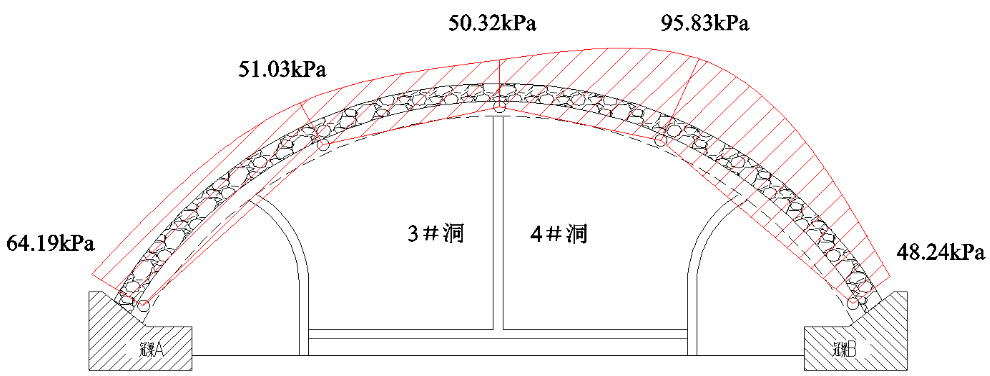
Figure 3.16 Monitoring diagram of primary branch earth pressure cell at section k8+441

The automatic monitoring data of the earth pressure cell were extracted and the variation curve of the earth pressure monitoring value of section k8+441 was shown in Figure 3.16. It can be seen that on April 26, as the station was gradually excavated inward, the earth pressure measured by all the earth pressure cell sensors in the primary branch of section k8+441 increased to a large extent. This situation lasted for about ten days and then gradually stabilized by May 10. However, the earth pressure value of the sensor increased again on June 4. At this time, the site was in the process of removing the middle door and side wall of the section. Judging from the variation trend in the figure, the range of change was large, indicating that the demolition of the middle door and side wall had a great impact on the earth pressure value of the station arch cover. The variation trend of the monitored values of the earth pressure cell of the second primary support is basically consistent with that of the first primary support.

The maximum earth pressure distribution diagram of section k8+441 is drawn based on the monitoring data, as shown in Figure 3.17. The maximum earth pressure of section k8+441 shows that the earth pressure value of hole No.3 TY-02 and TY-06 and hole No.4 TY-11 of section k8+441 is larger than other sensors. In particular, the position of the waist of the arch of No. 4 hole is subjected to great earth pressure at the first and second primary branches.



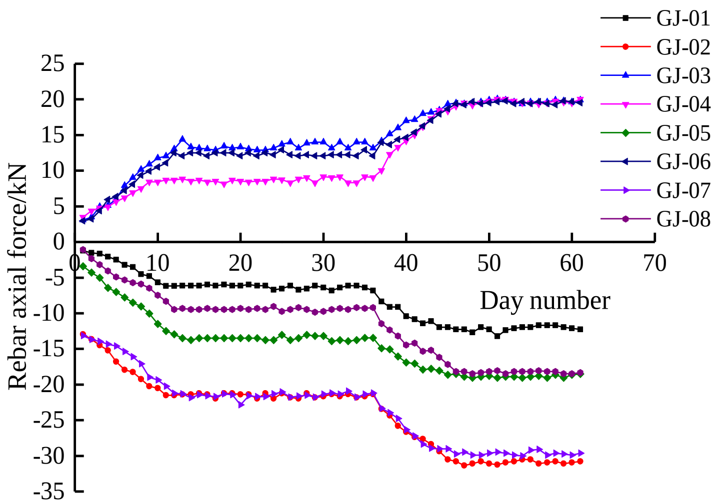
(a) Maximum earth pressure distribution at the first initial support



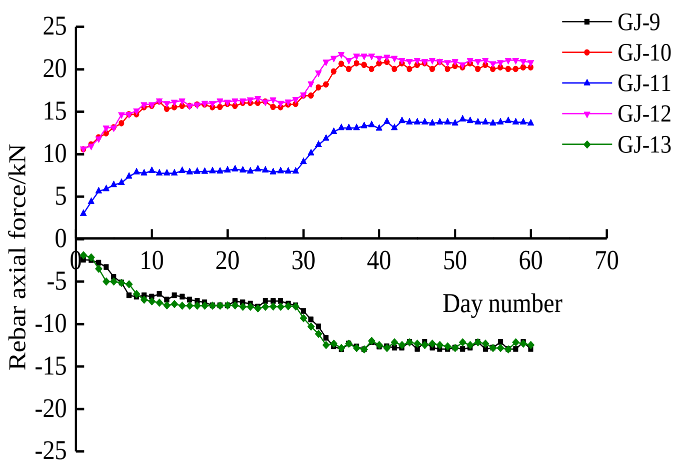
（b）Maximum earth pressure distribution at the second initial support

Figure 3.17 Distribution map of maximum earth pressure at section k8+441

3.4.2. *Analysis of stress value of steel arch in railway station*



（a）Rebar gauge monitoring at the first initial support



（b）Rebar gauge monitoring at the second initial support

Figure 3.18 Monitoring chart of reinforcement meter for initial support at section k8+441

Extract steel bar meter automatic monitoring data, draw the k8 + 441 section curves of reinforcing steel bar meter monitoring data, as shown in figure 3.18, the figure can be seen from April 26 to install sensors with further excavation section, the monitoring of reinforced axial force values are rising gradually, this state until May 6 or so, with the change of earth pressure box are basically identical. On June 4, the section of the middle door and the side wall of the guide tunnel were dismantled at the station, and the reinforcement axial force of the steel arch frame increased further, indicating that the dismantling of the side wall of the middle door and the side wall of the guide tunnel also had a great influence on the reinforcement axial force.

Among them, for the first primary branch numbered GJ-03, GJ-04 and GJ-06, GJ-01, GJ-02, GJ-05, GJ-07 and GJ-08, and for the second primary branch numbered GJ-10, GJ-11 and GJ-12, they are in a state of compression. GJ-09 and GJ-13 are in tension state. For section K8 +441, the axial force of reinforcement at the waist of the arch is also larger than that at other monitoring points, which is basically consistent with the distribution law of the maximum earth pressure.

The above analysis shows that for the initial support of section K8 +441, the stress on the section is mainly concentrated at the waist of the arch. Relevant personnel should be arranged here to carry out regular monitoring every day. In case of abnormal numerical changes, support and reinforcement should be carried out at this position immediately.

3.4.3. Analysis of the strain value at the partition wall in the station

Through the monitoring information management module, the automatic monitoring data of the strain gauges next to the station are extracted, and the k8+441 cross-section strain gauge monitoring data change curve is drawn, as shown in Figure 3.19. It can be seen from the figure that the installation of the strain gauge began on April 26 With the continuous excavation of the section inward, the strain gauge has continued to rise in the next more than one month, indicating that the next door position is subject to increasing pressure from the arch cover as the station excavates inward, and then When the next wall is removed at the station, the value of the strain gauge tends to stabilize.

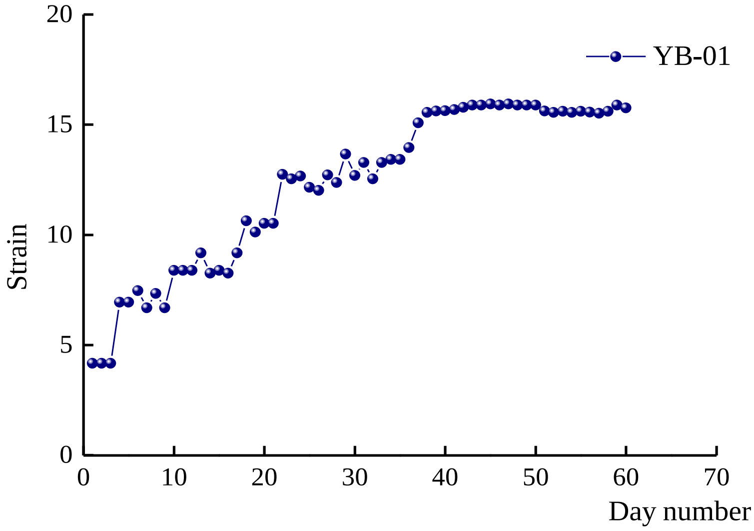
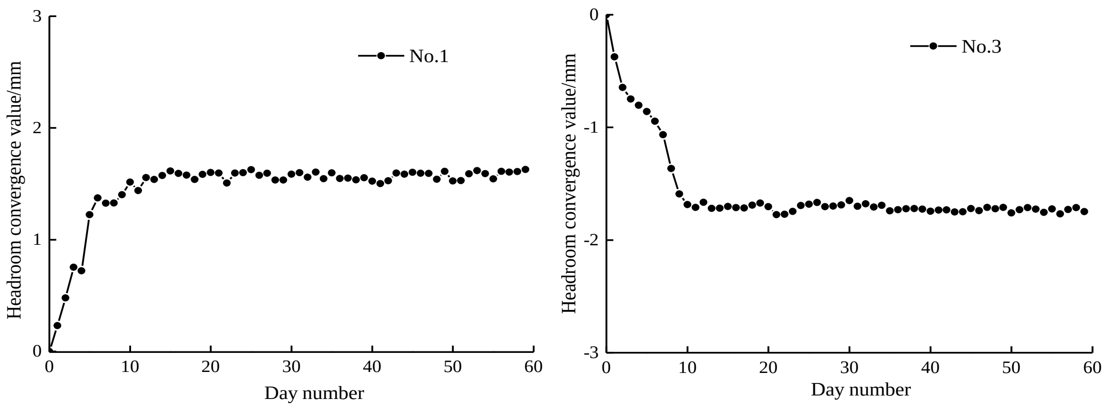


Figure 3.19 Strain curve of partition wall in section k8+441

3.4.4. Analysis of convergence value of clearance of high side wall

The laser rangefinder is used to monitor the convergence displacement of the clearance of the high side wall during the excavation of the lower part of Qingniwa Bridge Station. Ten laser rangefinder are installed within 100m of the excavation of the lower part of the main body, and one is installed every 10m. The data measured by the laser rangefinder are used to monitor and warn the excavation of the lower part of the main body of the station. The representative data of No. 1, 3, 5 and 7 laser rangefinders were extracted. Figure 3.20 shows the monitoring data of No. 1, 3, 5 and 7 laser rangefinders from September 17, 2020 (Day 0 in the figure) to November 15, 2020.



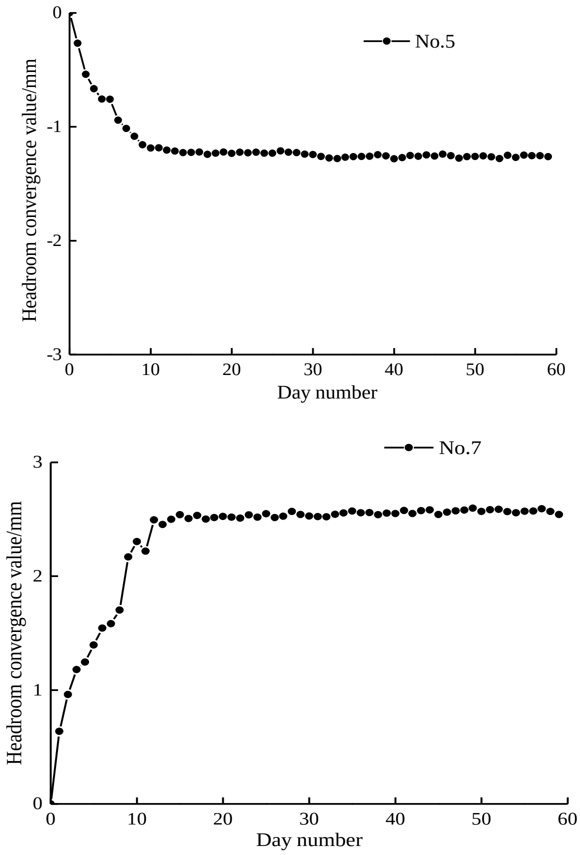


Figure 3.20 High side wall headroom convergence value monitoring chart

As can be seen from the figure, in the nearly two months monitored by the laser rangefinder, the clearance convergence values of the main excavation at the lower part of the station measured by the laser rangefinder 1, 3, 5 and 7 showed an upward trend in the first ten days or so and then stabilized within 3mm. The other laser rangefinder also controlled within 3mm. It can be seen that the main body of the lower part of the station is relatively stable in the excavation process, and no obvious mutation was found. The convergent displacement of the side wall can be well controlled according to the current construction method.

3.5. Construction suggestions of arch covering station based on monitoring information

Combined with the automatic monitoring information data analysis of typical sections in Section 3.4, the following suggestions are put forward for the construction of the arched cover station:

(1) from the earth pressure cells and reinforcement of monitoring data, you can see that the upper arch waist, arch, arch shoulder and arch foot around the biggest earth pressure monitoring points and the reinforcement method of axial force is generally occur in the arch cover door removed part of the construction of subway station, explain in arch cover construction should focus on the control of next door's demolition of length, In order to avoid the damage caused by excessive or uneven earth pressure on the arch caused by excessive length of demolition, and if the stress continues to increase, the supporting parameters of the arch should be optimized to form an optimization scheme.

(2) can be seen from the monitoring data of strain gauge, the station early in the demolition of the next position before and at the beginning of the second branch applied in the process of stress change is bigger, suggested that can be applied at the beginning of the subway station support for process, to the next door to the reinforcement measures, so as not to cause the door by the arch cover pressure caused by fracture.

(3) from the laser range finder for high sidewall convergence value clearance monitoring can be seen that side lower part of the station did not change the larger displacement, but look to combine the construction of the subway station, the station structure is only a part of the length of the excavation, as the continued excavation of lower part of the station structure, the construction of still response to high sidewall headroom convergence value for real-time monitoring, For the monitoring section with a large trend of change, the supporting parameters at the position of the high side wall, such as steel pipe pile, prestressed anchor rod and other relevant parameters, should be optimized and designed to form an optimization scheme.

3.6. Chapter summary

Taking Qingniwa Bridge Station of Dalian Metro Line 5 as the engineering background, this chapter first analyzes the necessity of the development of the monitoring information management module of the arch cover method station, and then introduces the hardware facilities and installation methods in this module. At the same time, the hardware layout scheme is formulated and explained in combination with the construction characteristics of the arch cover method. Automated monitoring and database technology are used to build the automatic acquisition and management module of construction information of arched cover railway station, and the automatic monitoring data of typical section k8+441 and the position of high side wall of railway station are extracted through the data query function of the module. According to the data change rule reflected by the monitoring data, Suggestions are provided for the construction scheme of the middle door, the arch cover and the high side wall of the subway station with arch cover.

4. Multi-factor Fuzzy Evaluation technology for risk analysis of arch covering station

4.1. Introduction

Due to the underground depth, large excavation section, poor stability of surrounding rock and complex construction technology of the arch cover subway station, there are many potential risk factors in the construction. It is not enough to manage the construction of the whole subway station only through the analysis of the automatic monitoring data of the station. Therefore, it is necessary to build a comprehensive risk evaluation module of the arch method subway station to analyze and evaluate the risks in the construction.

This chapter takes Dalian Metro Line 5 Qingniwa Bridge Station Project as the background, through the steps of risk identification, evaluation and countermeasures, carries on the research of risk analysis multi-factor fuzzy evaluation technology, and constructs the arch method station risk comprehensive evaluation module. The module type arch cover method based on Analytic Hierarchy Process (AHP), the subway station construction risk evaluation indexes, and stored with various indicators of risk weights, the use of expert evaluation method of the station construction risk probability and severity of the construction of total risk evaluation, according to the results of calculation module of risk valuation formulated the corresponding risk countermeasure, It provides some reference basis for the risk management of the project.

4.2. Project overview

Qingniwa Bridge Station is located at the intersection of Youhui Street and Wuhui Road, and is arranged along Youhui Street in a north-south direction. The terrain in the site has great ups and downs. The ground elevation within the station range from 16.35 to 21.89m, and the terrain is high in the south and low in the north. The length of Qingniwa Bridge Station is 222.7m, and the width of standard section is 22.4m. The construction method of underground digging arch cover is adopted. The main body of the station is an island station with two floors underground. The width of the platform is 13.3m, and the roof of the station is covered with soil about 17.6-22.5m. The left and right lines of the small mileage end of the station are the mine interval from Labor Park Station to Qingniwa Bridge Station, while the left and right lines of the large mileage end are the shield tunneling interval from Qingniwa Bridge Station to the railway station, and the tunneling will be received in this station. The location map of Qingniwa Bridge Station is shown in Figure 4.1.

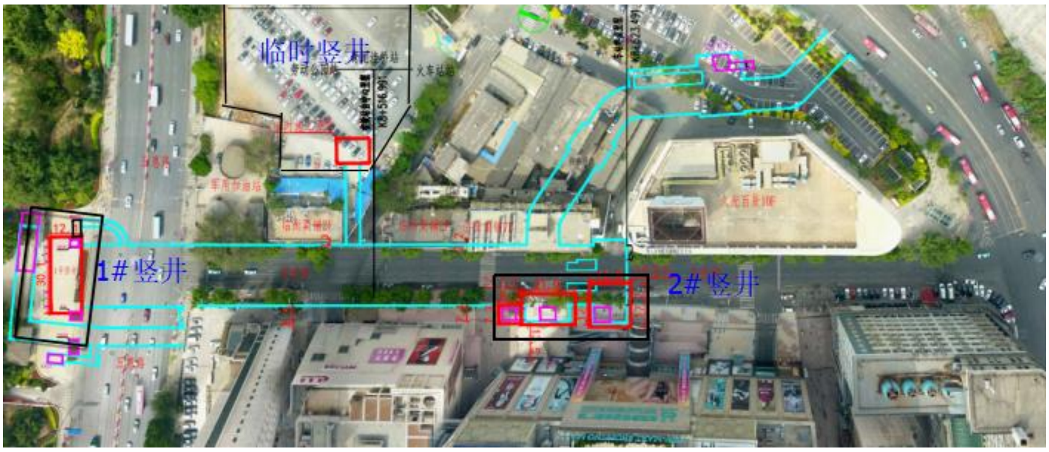


Figure 4.1 Location map of Qingniwa Station

(1) Engineering geology

According to the drilling survey report, the main rock and soil layers are plain fill, silty clay, gravel, strongly weathered slate, and moderately weathered slate, with diabase in some areas. The bottom of pilot tunnels 1 and 2 is located 24.3m below the ground, and the bottoms of pilot tunnels 3 and 4 are located 21.7m below the ground. They are all located in a moderately weathered slate formation. The details are shown in Figure 4.2:

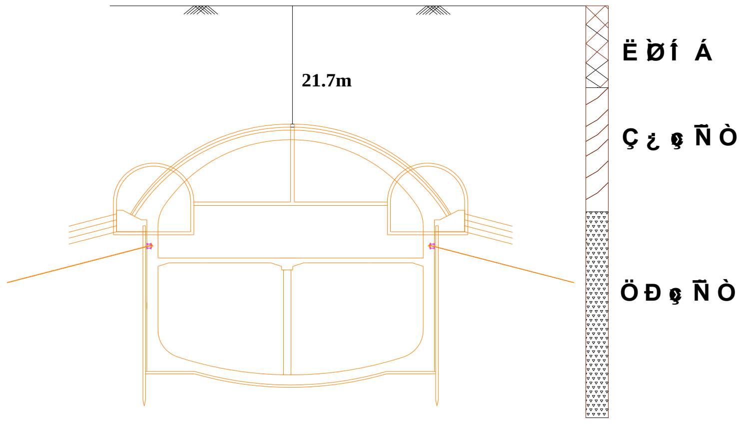


Figure 4.2 Geological profile

The inner layer of the station is composed of plain fill, silty clay, gravel, SLATE and diabase from top to bottom. The station is located in the highly weathered and moderately weathered strata. The maximum depth of the station is 22m, and the minimum depth is 17m. Within the small mileage of 60m, the station is moderately weathered SLATE strata (there are two guide tunnels between the tunnels). The remaining 131m upper tunnel is located in diabase strata (3 tunnels between the caves).

The groundwater type of the survey site is phreatic water, which can be divided into pore water of the Quaternary loose layer and bedrock fissure water according to its occurrence conditions. Due to the complex lithology changes of bedrock, the distribution regularity of bedrock fissure water is poor and the water abundance is extremely uneven. During the exploration period, the buried depth of the stable groundwater level is 5.80~6.20m and the water level elevation is 15.10~16.10m.

（2） Surrounding buildings

Shaft No.1 of Qingniwa Bridge Station is located at the north gate of Labor Park. The statistics of surrounding buildings are shown in Table 4.1.

Table 4.1 Statistical table of main buildings around No. 1 shaft of Qingniwa Bridge Station

Serial number	Name	Structure type	Relationship with the shaft
1	Power pipe gallery	Concrete	The closest horizontal distance is 12.9m

2	Basement	Brick-concrete structure	The closest horizontal distance is 28.2m

The east side of the station is near Yongjingtai and the elevation of Dashang Group, and the west side is near the military gas station and multi-storey shops. The side guide tunnel of the main structure of the station enters the basement within a range of 1.3m, affecting the mileage range of the station from k8+452.071 to k8+491.321. The gas station is a 32656 military gas station of Shenyang Military Region, Grade 2, with 4 oil tanks, a total volume of 110m^3, a buried depth of about 3.5m-4m, and 4 oil guns. The minimum horizontal distance between the gas station building and the initial support of the main structure is 0.02m, and the mileage range of the station affected is k8+445.911~ k8+473.511.

McKellar is a concrete frame shear wall structure with 8 floors above the ground and 2 floors below the ground. The foundation type is shallow foundation. The minimum horizontal distance between the basement structure edge line and the initial support of the main structure is 5.94m, and the mileage range of the station affected is k8+504.331~ k8+555.421. The storefront is a three-storey brick concrete structure on the ground, and the foundation type is shallow. The main structure of the station is 0.09m into the building, and the mileage range of the station is k8+520.741~ k8+553.061.

Dashang Xinmat is a concrete frame shear wall structure with 7 floors above the ground and 2 floors below the ground. The foundation type is shallow. The minimum horizontal distance between the edge line of basement structure and the initial support of the main structure is 7.26m, and the minimum horizontal distance between the initial support of No.2 shaft wall is 3.16m. The range of station mileage affected is k8+577.791~ k8+601.191. The storefront is a 7-storey brick concrete structure on the ground, and the foundation type is shallow. The minimum horizontal distance from the initial support of the main structure is 0.31m, and the minimum horizontal distance from the initial support of the No.2 vertical shaft is 0.51m. The range of station mileage affected is k8+554.351~ k8+601.191.

The distribution of structures around the station is shown in Figure 4.3.

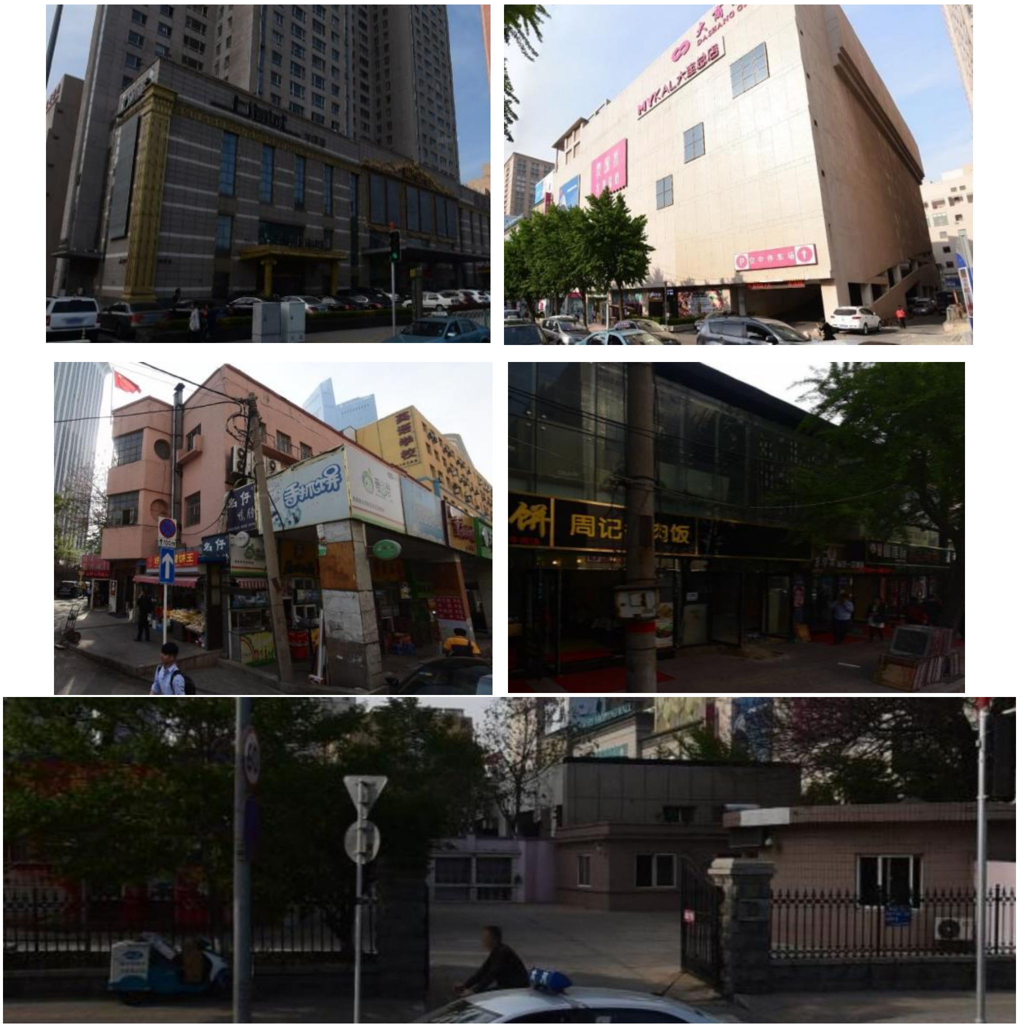


Figure 4.3 Images of buildings around the station

(3) Underground pipeline

The station runs through the medium pressure gas pipeline, the buried depth of the pipeline is about 2m, the pipe diameter is 300mm, the material is steel, and the power pipe gallery is penetrated, the buried depth of the pipe gallery is about 3.8m, the specification is 2000*2000mm, and the material is concrete. Pipelines around the shaft are mainly laid along friendly roads: Street lamp pipelines, communication cable, transportation pipe, gas pipe, electrical, etc., minimum distance shaft horizontal distance of 3.9 m, 2 condition by the actual digging Wells road scheme in pipelines found line eight root, the rest without actual digging out, through the current visible all kinds of geophysical prospecting figure line a total of 19 roots, specific pipeline situation are shown in table 4.2 below:

Table 4.2 Statistical table of pipeline situation around No. 1 shaft of Qingniwa Bridge Station

Name	Diameter and material	Depth （m）	Distribution
Street light pipe	DN300 copper	0.42	Arrange along Friendship Road
GYTS	200*100	0.6	Arrange along Friendship Road
Gas pipeline	DN300 steel	0.97	Arrange along Friendship Road
Power pipe	10kVcable	1.0	Arrange along Friendship Road

4.3. Theoretical method

4.3.1. Analytic Hierarchy Process

Analytic Hierarchy Process[45] (AHP) is a systematic and hierarchical analysis method that combines qualitative and quantitative analysis. This method decomposes the factors related to decision into target, criterion, index and so on, and makes the thinking process of decision mathematically by using less quantitative information, so as to provide a simple decision method for the complex decision problems with multiple objectives, multiple criteria or no structure characteristics. The basic steps are as follows:

（1） Establishment of hierarchical structure model. According to the hierarchical model, complex engineering problems are decomposed according to different levels, and each level is divided into several elements, and then these elements are grouped. Finally, a multi-level evaluation model is established for easy analysis.

（2） Construction of judgment matrix. The judgment matrix is A matrix in which n factors in the factor layer under the condition layer are pairwise compared to determine their relative importance. The judgment matrix A is an n-order matrix composed of a_{ij}.

$$\mathbf{A}=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{4.1}$$

Where, a_{ij} represents the degree of relative importance of factor *i* to factor *j*; if the value of a_{ij} is greater than 1, it means that factor *i* is more important than factor *j*; if the value of a_{ij} is less than 1, it means that factor *j* is more important than factor *i*; and the degree of relative importance between factor *i* and factor *j* is expressed by the specific value of the risk scale. This module selects the risk score judgment table on scale 1-9, as shown in Table 4.3.

Table 4.3 Risk scale score table

Scale	Definition (compare factors *i* and *j*)
1	Factor *i* is equally important than j
3	Factor *i* is slightly more important than *j*
5	Factor *i* is stronger than *j*
7	Factor *i* is more important than *j*
9	Factor *i* is absolutely more important than *j*
2，4，6，8	The median value of two adjacent judgment factors
reciprocal	The opposite of the above importance, that is, the situation where *j* is more important than *i*

(3) Hierarchical list sorting and its consistency check.

The judgment matrix is normalized according to the column vector, then the row sum is calculated and normalized into ω. The maximum eigenvalue λ_{max} of each judgment matrix is calculated according to formula (4.2), and then the consistency index CI is calculated according to formula (4.3). When CI=0, it indicates that the judgment matrix has complete consistency. The larger the value of CI, the worse the consistency of the judgment matrix is. CR value is calculated by formula (4.4). When CR<0.1, it indicates that the judgment matrix has good consistency; otherwise, it needs to be adjusted. Table 4.4 shows the average random consistency index.

$$\mathbf{A}\omega=\lambda_{max}\omega \tag{4.2}$$

$$CI=\frac{\lambda_{max}-n}{n-1} \tag{4.3}$$

$$CR=\frac{CI}{RI} \tag{4.4}$$

Table 4.4 Average random consistency index

Order	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.12	1.36	1.41	1.46

(4) Hierarchical total ordering and its consistency test

Hierarchical total ordering is to calculate the weight of relative importance of each target layer in the hierarchy. The process is the same as that of hierarchical single ordering, which also needs to carry out consistency test.

4.3.2. Fuzzy criterion

Fuzzy Comprehensive Evaluation method[46-47] is a method that transforms qualitative evaluation into quantitative evaluation according to the membership theory of fuzzy mathematics. The basic steps of the specific method are as follows:

(1) Design risk valuation model

Risk valuation is a numerical estimation of the occurrence probability and risk hazard degree of engineering risks. The risk valuation standard adopted in this paper is as follows:

$$R=P\cdot S \tag{4.5}$$

In the formula, R represents the risk of the project, P represents the probability of risk occurrence, and S represents the danger degree of the risk.

(2) Expert scoring standards

The probability of risk occurrence is divided into five levels according to the probability of risk occurrence, and the specific scoring criteria are shown in Table 4.5. According to the degree of loss caused by the occurrence of the risk, the degree of risk is divided into five levels, and the specific scoring criteria are shown in Table 4.6.

Table 4.5 Risk occurrence probability estimation table

Level	Valuation	Explain
1	1	Impossible

2	2	Infrequence
3	3	Sporadic
4	4	Possible
5	5	Frequent

Table 4.6 Risk hazard estimation table

Level	Valuation	Explain
1	1	Negligible
2	2	Considerable
3	3	Cautious
4	4	Serious
5	5	Very serious

(3) The risk valuation matrix was established, in which the risk valuation grade was shown in Table 4.7.

Table 4.7 Risk valuation rating table

Risk level	Valuation	Explain
Slight	1~5	The risk is negligible and there is no need for additional measures
Medium	5~10	The risks are noteworthy and require the preparation of preventive measures
Serious	10~15	Preventive measures need to be implemented to reduce risks
Catastrophic	15~25	The risks are high and the specification of a control scheme is mandatory

(4) Fuzzy evaluation

Starting from the lowest level, the weight set of each level obtained by the analytic hierarchy process and the risk valuation matrix are used to calculate the risk valuation of each factor. The calculation formula is as follows:

$$B = \omega \cdot R \tag{4.6}$$

In the formula, ω is the weight set of risk factors at this level, and R is the risk evaluation matrix scored by experts.

4.4. Risk analysis of arch cover method station

4.4.1. Risk Identification

Risk identification is the basis of risk assessment. Risk identification is mainly to find out the risk factors in the project, and to qualitatively determine the nature of the risk, the possibility of its occurrence and the extent of its impact on the project. The key to risk identification is to recognize risk, that is, to use the point of view of system theory to carry out a comprehensive and comprehensive analysis of the project, to find out the process of potential risk factors. Risk identification of subway station construction[48] should follow the principles of systematicness, scientificity, applicability and dynamics.

On the basis of the existing risk assessment theory research[9,11,12], this chapter identifies the risk factors that may be faced by the construction of arch cover subway station in combination with the construction risk mechanism of subway station and the construction characteristics of arch cover subway station. The risk sources of the subway station are mainly divided into three parts: monitoring risk factors, environmental risk factors and excavation risk factors.

The index system of construction risk level of subway station finally established is shown in Figure 4.4.

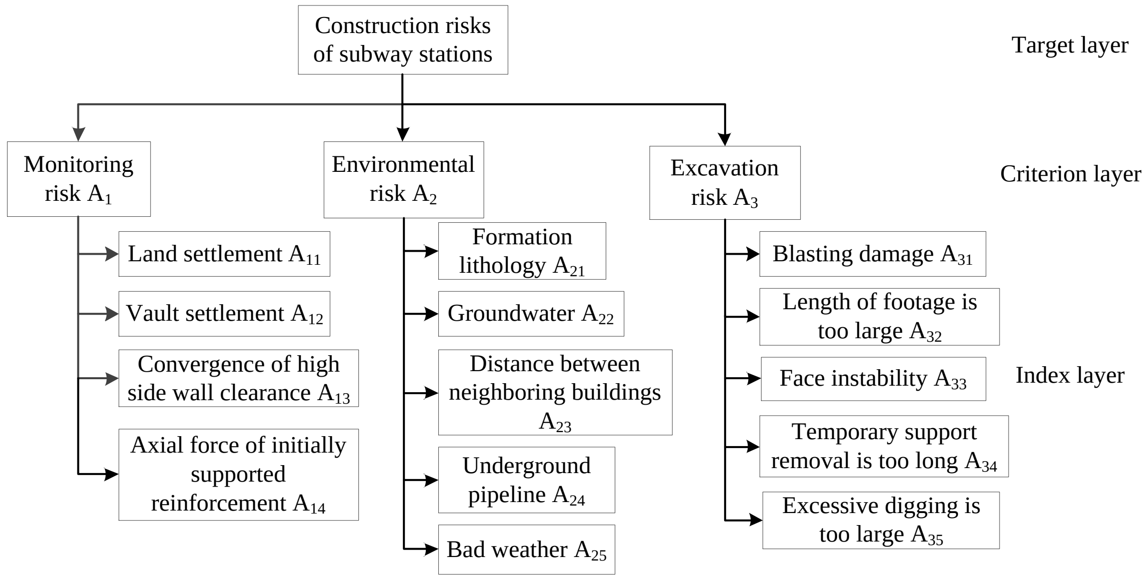


Figure 4.4 Subway station construction risk hierarchy index system

Combined with the subordinate relationship of risk factors in subway stations, the risk factors in subway stations are divided into first-level and second-level indexes. The first-level index includes construction risk, monitoring risk and environmental risk of subway stations, while the second-level index includes 14 risk factors, such as blasting damage, monitoring displacement change and underground pipelines.

4.4.2. Risk assessment

After the identification of the risks in the construction of subway stations, the construction risks of subway stations are evaluated, and each risk in the risk identification report is quantitatively analyzed and described to obtain the proportion of the adverse impact of each major risk factors on the subway station project. First, each risk factor in the construction is evaluated. In this paper, the risk assessment of subway station construction mainly includes the following two aspects:

(1) Evaluate the probability of occurrence of risk events during the construction period of the subway station.

(2) Evaluate the degree of danger caused by the occurrence of risk events during the

construction period of the subway station.

Experts are invited to judge the relative importance of the indicators in the above-mentioned hierarchical risk structure model, combined with the 1-9 scale method to construct a judgment matrix for the target layer and the criterion layer as shown in Table 4.8.

Table 4.8 Target layer A weight judgment matrix

A	A_1	A_2	A_3
A_1	1	2	1/3
A_2	1/2	1	1/5
A_3	3	5	1

1. Risk assessment based on monitoring measurements

The monitoring risk factors of subway station are the automatic monitoring information and manual monitoring information introduced in Chapter 3, including the settlement value of the ground surface, the settlement value of the station vault, the clearance convergence value of the high side wall and the axial force value of the initial reinforcement. Risk evaluation of the risk degree is mainly based on the monitoring value of alert interval, in different range of monitoring values will give different evaluation points, the construction of monitoring measurement and the blue mud hollow bridge station construction monitor control standard in monitoring the alert value comparison evaluation, monitoring and risk degree score interval as shown in Table 4.9.

Table 4.9 Risk score indicators based on monitoring measurements

Risk valuation	Land settlement/mm	Vault settlement/mm	High side wall clearance convergence/mm	Initial reinforcement axial force/MPa
1	<20	<10	<4	<200
2	20~28	10~14	4~7	200~252
3~4	28~40	14~20	7~10	252~360
5	>40	>20	>10	>360

The probability of occurrence of monitoring risks is mainly based on the data characteristics of station monitoring points, as shown in Table 4.10, which is the scoring interval table of occurrence probability of monitoring risks.

Table 4.10 Risk occurrence probability evaluation index based on monitoring measurement

Risk valuation	Monitoring data characteristics
1	The monitoring points in the subway station are basically normal and remain within the control value for a long time.
2	The data of some station monitoring points are abnormal or close to the warning value for a long time;
3~4	Some monitoring points in the station have exceeded the limit for a long time, and there is no convergence trend.
5	The data of monitoring points in some parts of the station have obvious abrupt changes and are still changing unsteadily

The weight judgment matrix of monitoring measurement risk in the criterion layer is shown in Table 4.11.

Table 4.11 Criterion layer A_1 weight judgment matrix

A_1	A_{11}	A_{12}	A_{13}	A_{14}
A_{11}	1	2	5	7
A_{12}	1/2	1	3	5
A_{13}	1/5	1/3	1	3
A_{14}	1/7	1/5	1/3	1

2. Environmental risk factors

The environmental risks of subway stations include stratum lithology, groundwater, underground pipeline distribution, the distance of adjacent buildings and the severity of weather. The weight judgment matrix of this criterion layer is shown in Table 4.12.

Table 4.12 Criterion layer A_2 weight judgment matrix

A_2	A_{21}	A_{22}	A_{23}	A_{24}	A_{25}
A_{21}	1	1/2	1/4	1/2	2
A_{22}	2	1	1/2	1/3	4
A_{23}	4	2	1	1	5
A_{24}	2	3	1	1	4
A_{25}	1/2	1/4	1/5	1/4	1

3. Risk factors of excavation

Combined with the construction process information and project overview in Chapter 3, the risk factors of subway station excavation are summarized, including blasting damage, excessive length of footage, instability of the face, excessive length of temporary disassembly and excessive and underexcavation. The weight judgment matrix of this criterion layer is shown in Table 4.13.

Table 4.13 Criterion layer A_3 weight judgment matrix

A_3	A_{31}	A_{32}	A_{33}	A_{34}	A_{35}
A_{31}	1	1/2	1/4	1/2	1/3
A_{32}	2	1	1/3	1	1/2
A_{33}	4	3	1	3	2
A_{34}	2	1	1/3	1	1/2
A_{35}	3	2	1/2	2	1

Monitoring risk A_1 is taken as an example to illustrate the calculation of weight. After summing up the judgment matrix of monitoring risk A_1 according to columns, the following results are obtained:

$$\omega_1 = \begin{pmatrix} 0.521 \\ 0.297 \\ 0.125 \\ 0.058 \end{pmatrix}$$

Calculate the largest characteristic root:

$$\lambda_{\max}=\sum_{i=1}^{n}\frac{(\overline{\mathbf{A}}\omega)_i}{n\omega_i}=\frac{2.146}{4\times0.521}+\frac{1.1225}{4\times0.297}+\frac{0.502}{4\times0.125}+\frac{0.2335}{4\times0.058}=4.069 \quad (4.7)$$

$$\mathrm{CI}=\frac{\lambda_{\max}-n}{n-1}=\frac{4.069-4}{4-1}=0.023 \quad (4.8)$$

$$\mathrm{CR}=\frac{\mathrm{CI}}{\mathrm{RI}}=\frac{0.023}{0.89}=0.026<0.1 \quad (4.9)$$

The results show that the consistency meets the requirements, and the ranking weight vector of each factor in the monitoring risk is:

$$\omega_1=\left[0.521,0.297,0.125,0.058\right]$$

In the same way, the weight vectors of factors in the target layer and other criterion layers are:

$$\omega=\left[0.23,0.122,0.648\right]$$

$$\omega_2=\left[0.11,0.177,0.339,0.314,0.06\right]$$

$$\omega_3=\left[0.082,0.137,0.4,0.137,0.244\right]$$

The consistency test results of the weighted judgment matrix are shown in Table 4.14. It can be seen that the designed judgment matrix meets the consistency requirements.

Table 4.14 Consistency check table

Judgment matrix	CI	CR	Conclusion
A	0.027	0.03	Meet
A_1	0.02	0.038	Meet
A_2	0.023	0.026	Meet
A_3	0.0095	0.016	Meet

The probability of occurrence of risk and the degree of risk are scored by expert score combining with the probability estimation table of occurrence of risk and the degree of risk of risk. The rating table of occurrence probability (P) and risk (S) of risk events is shown in Table 4.15.

Table 4.15 Risk valuation results

Criterion	Risk factors	*P*	*S*	*R*
Monitor risk	Surface settlement value	2	3	6
	Vault settlement value	2	3	6
	Headroom convergence value	2	3	6
	Rebar axial force value	1	2	2
Environmental risk	Formation lithology	3	2	6
	groundwater	4	3	12
	Distance between neighboring buildings	4	2	8
	Underground pipeline distribution	4	2	8
	bad weather	2	2	4
Excavation risk	Blasting damage	3	4	12
	Length of footage is too long	3	3	9
	Face instability	3	4	12
	Temporary dismantling length is too long	3	3	9
	Excessive digging is too large	3	4	12

According to the weight set of risk factor index corresponding to different criterion layer and the index score in the risk valuation table obtained above, the risk valuation of criterion layer is calculated. Taking the excavation risk as an example, the calculated results are as follows.

$$R_{A_3}=\omega_3\cdot\begin{pmatrix}R_{A_{31}}\\R_{A_{32}}\\R_{A_{33}}\\R_{A_{34}}\\R_{A_{35}}\end{pmatrix}=\left[0.082,0.137,0.4,0.137,0.244\right]\cdot\begin{pmatrix}12\\9\\8\\9\\12\end{pmatrix} \tag{4.10}$$
$$=11.178$$

In the same way, the risk evaluation values of other criterion layers were obtained. Fig. 4.5 shows the bar chart of the comprehensive risk evaluation values of each criterion layer. Finally, the total risk evaluation valuation of the subway station was calculated based on the risk evaluation values of the criterion layer, R=9.572.

$$R_A = \omega \cdot \begin{pmatrix} R_{A_1} \\ R_{A_2} \\ R_{A_3} \end{pmatrix} = [0.23, 0.122, 0.648] \cdot \begin{pmatrix} 6.006 \\ 8.248 \\ 11.178 \end{pmatrix} = 9.572 \tag{4.11}$$

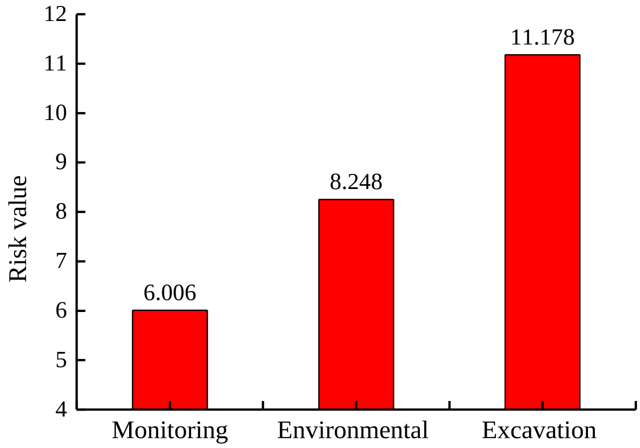


Figure 4.5 Histogram of risk value at the criterion level

4.4.3. Risk countermeasures

After sorting out the results of the risk score in the construction, the risk countermeasures of the subway station construction are formulated for the specific risks, so as to avoid or reduce the damage caused by the risks and ensure the safety of the subway construction.

According to the analysis of the risk evaluation values of each layer, the overall risk value of subway station construction is 9.572, which is at the second-level risk level. The construction risks of this subway station, from high to low, are: excavation risk, environmental risk and monitoring risk. Among them, the risk value of excavation risk reaches 11.178, and the risk grade is level 3. Preventive measures should be taken to reduce the risk.

For monitoring risks, the monitoring and measurement of excavation support should be strengthened and the results should be fed back in time. Monitoring points are scattered around ground structures and underground pipelines. According to the excavation conditions and monitoring feedback data, support parameters are adjusted and optimized in time to ensure construction safety. At the same time, monitoring of groundwater level is strengthened to ensure that the groundwater level is located 1m below the excavation face.

In view of the environmental risk, because of the complex geological conditions of the subway station, the risk generated by the surrounding environment should be managed and controlled during the construction of the station. Before construction, the location of underground pipelines should be confirmed in detail. For groundwater, advance geological prediction should be strengthened during construction, and the fault and broken zone should be reinforced and grouted. Before construction, it is necessary to investigate the specific foundation form of the building and the geological conditions near the building. If necessary, grouting should be carried out for the foundation of the building. If the settlement of the building is too large, the excavation should be stopped immediately and all the construction face should be closed. At the same time, the buildings and the soil in the excavation area are further reinforced by grouting.

In view of the excavation risk, because the excavation and support of the pilot tunnel is constructed by the step method, the stratum within the excavation area is plain fill, gravel, and weathered slate in order from top to bottom. The unevenness of the filling is relatively high. High, good water permeability, poor self-stability, easy to collapse. Based on the above risk status, the following measures should be taken:

(1) Excavation and support shall be carried out in accordance with the design and specification requirements, and the support shall be erected in time.

(2) Supervise the construction team to do a good job of drainage and waterproofing to ensure that there is no water during the excavation process.

(3) The footage of each cycle of earth and rock excavation should meet the requirements of the specification to reduce disturbance to the surrounding soil and avoid landslides. After the excavation is completed, the initial support should be carried out immediately, so as to be closed step by step.

(4) During the excavation process, the geological survey should be done well, and each excavation work shift should be assigned with relevant technical personnel for management to ensure the implementation of construction technology links and ensure standardized operations.

(5) Increase the advance geological forecast and advance reinforcement measures to ensure the stability of the variable interface.

(6) When the surface settlement deformation is too large or the deformation rate is too fast during the excavation process, the excavation and dismantling sequence should be stopped first,

and emergency plans should be taken for different forecast levels.

(7) Strictly control the vibration speed of excavation and blasting.

4.5. Comprehensive risk assessment module

(1) Module development route

The framework construction of this module is mainly carried out according to the process of risk analysis in the previous section. First, risks are identified, each risk is scored, and finally the overall risk valuation is calculated. The overall framework of the module is shown in Figure 4.6.

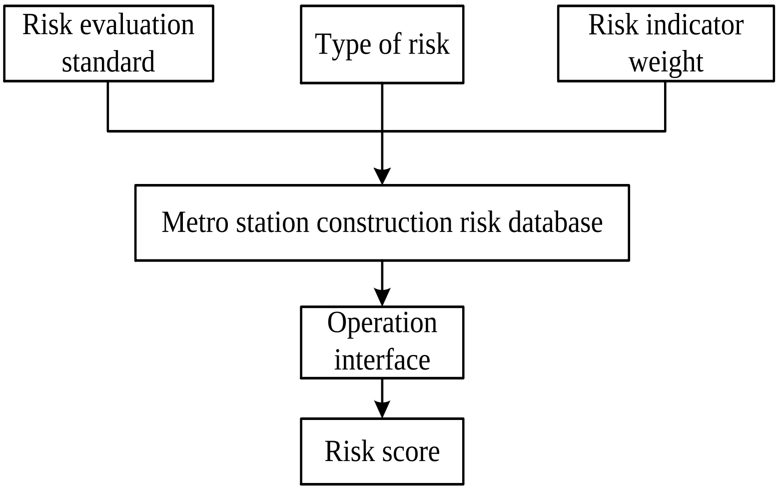


Figure 4.6 Framework diagram of risk comprehensive evaluation module

(2) Risk information database construction

The risk information database in the module is built, which mainly includes risk types, risk evaluation indexes and risk index weights. The definitions of fields in the risk information database for arch construction are shown in Table 4.16.

Table 4.16 Risk information field property description table

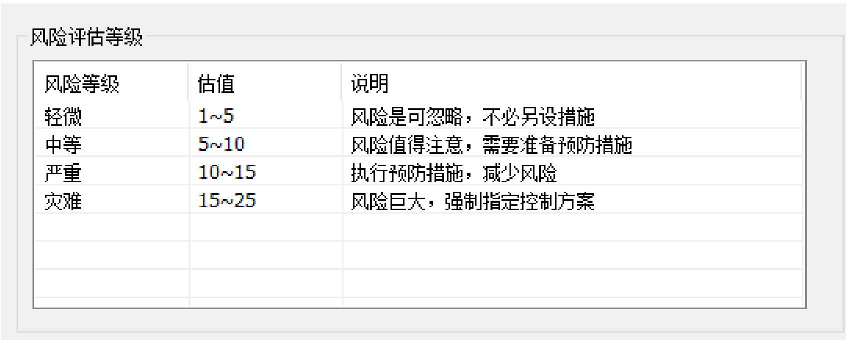
Description	Field Name	Data type
Risk level	RiskLevel	Number
Risk value	RiskValuation	Number
Risk characteristics	RiskCharacteristics	Txt

Risk factors	RiskFactors	Txt
Risk score	RiskScore	Number
Risk weight	RiskWeight	Number

(3)　Module realization and function

The risk assessment model described in the previous section is used to establish the multi-factor fuzzy evaluation module for the risk analysis of the arched metro station. In this module, the risk index system, the weight value of the index, the scoring standard of the index display, and the risk evaluation and calculation are recorded. Therefore, the function of this module is mainly divided into three parts: risk grade division, reference standard of grading and calculation of risk score.

1、Risk rating. The system input the risk valuation grade table established in this paper, divide the different risk grades in the module, and explain the risk score range of each grade, as shown in Fig. 4.7.


风险评估等级

风险等级	估值	说明
轻微	1~5	风险是可忽略，不必另设措施
中等	5~10	风险值得注意，需要准备预防措施
严重	10~15	执行预防措施，减少风险
灾难	15~25	风险巨大，强制指定控制方案

Figure 4.7 Risk assessment level query

2、Grading and grading reference standards. The characteristic information of each risk factor in the risk index system of subway station with arch cover method is input in the module, and the grading characteristics of a designated risk factor are explained by querying the primary and secondary indexes with conditions, which can be used as a reference for the risk scoring. As shown in Figure 4.8, the query interface of risk scoring standard is presented.

Figure 4.8 Risk score criteria query

3、Risk score calculation. By scoring the risk occurrence probability and risk degree of each risk factor, the score ranges from 1 to 5. Click Calculate to calculate the final total risk value based on the risk weight in the project. Figure 4.9 shows the risk score calculation interface.

Figure 4.9 Risk score calculation

4.6. Chapter summary

In order to build the risk information database in the risk comprehensive evaluation module of the arched metro station, this chapter establishes the three-level risk evaluation system of the arched metro station construction through the analytic hierarchy process, which makes the risks existing in the construction of the subway station more hierarchical and clear. Using expert evaluation method to the relative importance of the hierarchy structural model of the risk factors, calculated weight of each risk factor, and recorded in the risk evaluation module, finally the module implementation of green mud hollow bridge station engineering three-level risk evaluation model of quantitative evaluation, the evaluation results show that the subway station construction risk valuation from high to low in turn is: Excavation risk, environmental risk, monitoring risk. The overall risk level of the station is level 2, but the risk level of excavation is level 3. Preventive measures should be taken to reduce the risk, which is basically consistent with the actual construction situation. Finally, relevant risk countermeasures for these three kinds of risks are summarized in this chapter to provide reference for the construction of the project.

5. Optimizing technology for construction parameters of metro station with arch cover method

5.1. Introduction

Through the risk analysis of the arch cover subway station, it can be seen that the construction risk of the subway station has reached three levels, and corresponding preventive measures should be taken. Due to the problems of poor stability of surrounding rock and complex construction method in the arch cover subway station engineering, it is easy to cause excessive deformation of surrounding rock in the construction, which leads to the station structure instability, seriously affects the construction period and cost of the project, and also brings hidden danger to the construction and operation safety of the subway station. Therefore, how to optimize the construction parameters so that it can be safely and efficiently constructed under such conditions has become a difficult and hot issue in engineering field.

This chapter to Dalian subway line 5 blue mud hollow bridge station as engineering background, the system of the dome cover building subway station construction parameter optimization module, the module by setting the optimization of construction parameters scope to call of particle swarm optimization program, the program combined with orthogonal experiment and numerical simulation of displacement, regression model and function of supporting cost, To realize the optimization design of the construction parameters of the arch cover subway station and form a new support scheme to guide the construction of the subway station.

5.2. Introduction to the algorithm

Particle swarm optimization algorithm[49] is a calculation method used for optimization. It refers to the process of guiding particles to approach the optimal solution through constant iteration and updating of the velocity and position of particles in a crowd. The algorithm can be thought of as in a space that is full of all kinds of particles, the space inside the particle has a fitness is determined by the objective function of optimization, and each particle has its own corresponding displacement and velocity vector, all particles in the space at a certain speed, communicate with each other constantly search and update the optimal value, to determine the process of the global optimal value.

If this algorithm is used as a mathematical model for calculation, it can be expressed as: In an n-dimensional space, there is a group of particle swarm composed of m particles, and the position of the *i*th particle can be expressed as: X_i=（x_{i1}，x_{i2}，...，x_{in}）, where i=（1，2，3，…，m）, the velocity of the particle traveling in space V_i=（v_{i1}，v_{i2}，…，v_{in}） the optimal position that the particle itself can search is expressed as: P_i=（p_{i1}，p_{i2}，…，p_{in}）, and the optimal position of the whole particle swarm is expressed as P_g=（p_{g1}，p_{g2}，…，p_{gn}）. Iterate through the following two iteration formulas.

$$v_i^{k+1} = \omega v_i^k + c_1 r_1 (P_i^k - X_i^k) + c_2 r_2 (P_g^k - X_i^k) \qquad (5.1)$$

$$X_i^{k+1} = X_i^k + v_i^{k+1} \qquad (5.2)$$

In formula, k represents the number of iterations, c_1 and c_2 are acceleration factors, also known as learning factors, r_1 and r_2 are random Numbers between 0 and 1, and w is inertia weight factor, generally 0.2 ~ 1.4.

When PSO is used for multi-dimensional parameter optimization, premature convergence is easy to occur. In order to solve this problem, w is adjusted according to the inertial weight method. The adjustment formula is as follows：

$$w=w_0\left[1-(\frac{k-1}{k})^n\right] \tag{5.3}$$

In formula, w_0 is a constant, k is the number of iterations, n is a constant.

With the constant optimization of particles, the population will get closer to the optimal solution, and the convergence speed can be accelerated by compressing a certain search space during the process of approaching. The space compression formula is as follows：

$$Y_{\max n}=b_0(y_{\max n}^k-v_{cn}^k)+v_{cn}^k \tag{5.4}$$

$$Y_{\max n}=b_0(y_{\max n}^k-v_{cn}^k)+v_{cn}^k \tag{5.5}$$

In formula, $Y_{\max n}$ is the upper boundary in the n-dimensional direction of the compressed space, $Y_{\max n}$ is the lower boundary of the n-dimensional direction of the compression space, b_0 is the compression factor between 0 and 1, $y_{\max n}^k$ is the n-dimensional maximum of the current k iterations, $y_{\min n}^k$ is the minimum value in the n-dimensional direction of the current k iterations, v_{cn}^k is the center-of-mass value in the n-dimensional direction of the current k iterations, and the center-of-mass value is the sum of the velocity assignments of the entire particle swarm for the current k iterations divided by the population number of particles (N). The optimization algorithm flow is shown in Figure 5.1.

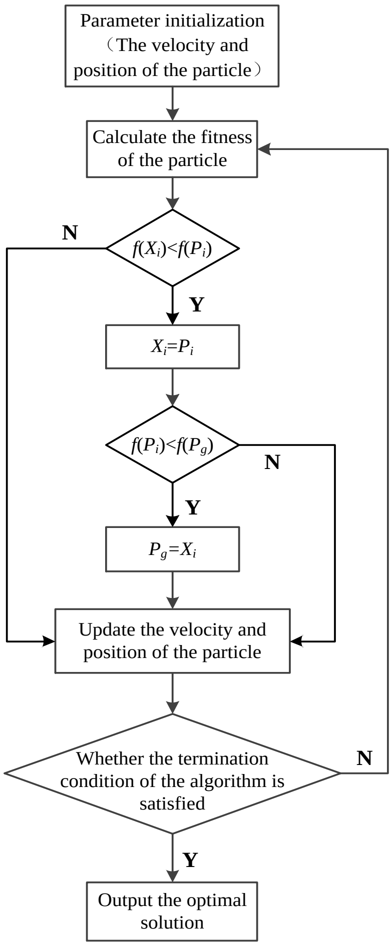


Figure 5.1 Flow chart of PSO algorithm

5.3. Establishment of optimization model for construction parameters of subway station

In the process of parameter optimization, support cost and stability of surrounding rock will change with the change of anchorage parameters. In order to solve this multi-objective optimization problem, displacement constraint conditions should be added to the optimization model. The displacement models of surrounding rock parameters are predicted by the numerical simulation method of orthogonal test scheme, and these displacement models are constrained to ensure the stability of surrounding rock.

According to site construction requirements，the representation form of the mathematical model that needs to be optimized is as follows:

$$\begin{cases} \min\ f(X) \\ s.t.\ g_i(X) \le g_i, \quad i = 1, 2, \cdots, n \end{cases} \tag{5.6}$$

In this formula, X is anchorage parameters, including anchor length (l), anchor spacing (s), anchor diameter (d), the thickness of spray layer (D) and the elastic modulus of spray layer. In this paper, $f(X)$ is the cost function of the support. $g_i(X)$ means the deform of surrounding rock and g_i represents the displacement constraint. The flow chart of anchorage parameter optimization is shown in Fig 5.2.

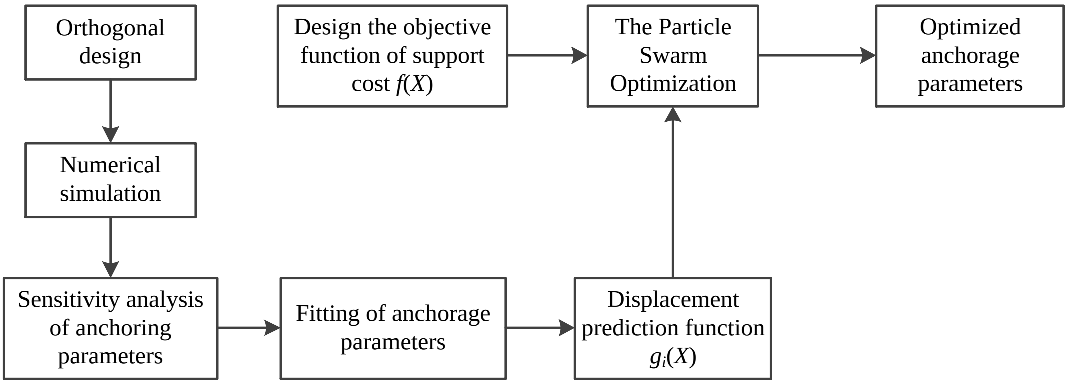


Figure 5.2 Anchoring parameter optimization process

5.4. *Establishment of optimization model for construction parameters of subway station*

5.4.1. *Optimization of Supporting Parameters of High Side Wall*

Taking Qingniwa Bridge Station of Dalian Metro Line 5 as the research object, according to the engineering design data, the high side wall of the station is supported by steel tube pile and prestressed anchor cable[55]. The numerical model of subway station was established by Flac^{3D} software. The geometric model size was 212m*40m*98m, and the constitutive relation of surrounding rock material was Mohr-Coulomb model. The unit type was Group entity unit, and the number of units was 109400. Cable structural unit is adopted for the prestressed anchor cable in the station. Considering that steel tube pile, crown beam and waist beam are simultaneously used to make it a continuous whole in fact, and the effect between pile and soil between piles needs to be considered, liner element considering equivalent thickness is adopted to simulate steel tube pile. The conversion formula is as follows.

$$h = 0.838D\sqrt[3]{\frac{1}{1+\frac{t}{D}}} \tag{5.7}$$

In the formula, D is the pile diameter of the steel pipe pile, t is the pile distance of the steel pipe pile, and h is the thickness of the equivalent underground wall.

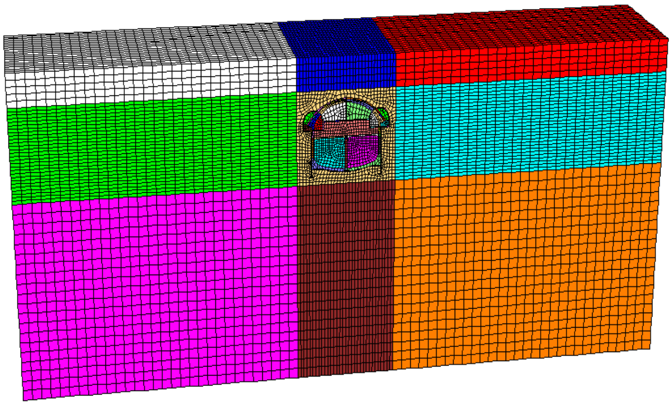


Figure 5.3 Numerical model

Table 5.1 Soil layer parameter table

Surrounding rock	E/MPa	μ	γ/kN·m^{-3}	c/kPa	φ/°
Plain fill	8	0.4	17	10	15
Silty clay	30	0.3	19	12	20
Strongly Weathered Quartzite	50	0.25	24	80	35
Moderately Weathered Diabase	1300	0.24	28.5	180	40

According to the drilling survey report, the main rock and soil layers are plain fill, silty clay, gravel, strongly weathered slate, and moderately weathered slate, with diabase in some areas. The geological parameters of the engineering soil are shown in Table 5.1, and the calculation model is shown in Figure 5.3.

Table 5.2 Orthogonal test

Factor	l(m)	S(m)	s(m)	D(cm)	a(mm)	b(mm)
Test 1	8	0.5	1.0	15	14.63	8.6
Test 2	8	0.8	1.2	20	14.3	8.12

Test 3	8	1.0	1.5	25	14.17	7.86
Test 4	8	1.2	1.8	30	13.46	6.57
Test 5	8	1.5	2.0	35	13.06	5.86
Test 6	9	0.5	1.2	25	13.11	6.03
Test 7	9	0.8	1.5	30	13.04	5.8
Test 8	9	1.0	1.8	35	12.74	5.15
Test 9	9	1.2	2.0	15	15.37	9.81
Test 10	9	1.5	1.0	20	14.6	8.61
Test 11	10	0.5	1.5	30	12.75	5.14
Test 12	10	0.8	1.8	35	12.69	4.97
Test 13	10	1.0	2.0	15	15.21	9.7
Test 14	10	1.2	1.2	20	14.7	8.85
Test 15	10	1.5	1.0	25	14.12	7.82
Test 16	11	0.5	1.8	35	12.34	4.28
Test 17	11	0.8	2.0	15	15.28	9.9
Test 18	11	1.0	1.0	20	14.69	8.8
Test 19	11	1.2	1.2	25	14.28	8.03
Test 20	11	1.5	1.5	30	13.62	6.85
Test 21	12	0.5	2.0	15	15.11	9.6
Test 22	12	0.8	1.0	20	14.4	8.31
Test 23	12	1.0	1.2	25	14.07	7.7
Test 24	12	1.2	1.5	30	13.43	6.5
Test 25	12	1.5	1.8	35	13.14	6
Range *a*	0.26	0.66	0.638	1.922	-	-
Range *b*	0.542	1.222	1.22	3.546	-	-
The mean of range	0.401	0.941	0.929	2.734	-	-

The spacing of steel pipe piles, the diameter of steel pipe piles, the length of prestressed anchor cables and the spacing of prestressed anchor cables are taken as orthogonal test factors.

According to the engineering construction requirements, the design of steel pipe pile spacing S: 0.5~1.5m, steel pipe pile diameter D: 15~35cm, the length of the prestressed anchor cable L: 8~12m, prestressed anchor cable spacing S: 1~2m. Based on these four parameters, an orthogonal table L25 (45) with 4 factors and 5 levels was established. Orthogonal tests were conducted with the settlement value of the vault A and the convergence value of the high side wall B as the research objects[56]. The designed 25 groups of test data were substituted into Flac^{3D} software for simulation calculation, and the calculation results are shown in Table 5.2.

In the numerical simulation, the displacement nephogram results of the subway station in Z direction and X direction are shown in Figure 5.4 and 5.5.

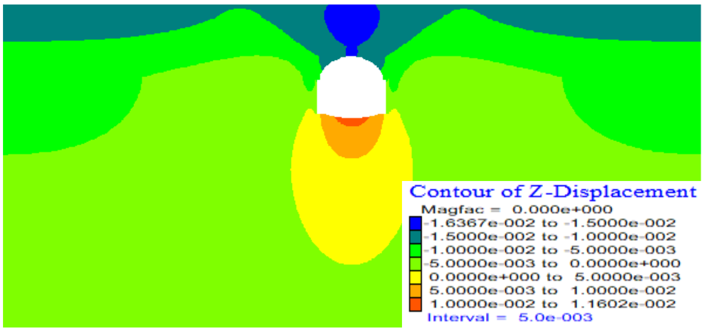


Figure 5.4 Displacement cloud map in Z direction

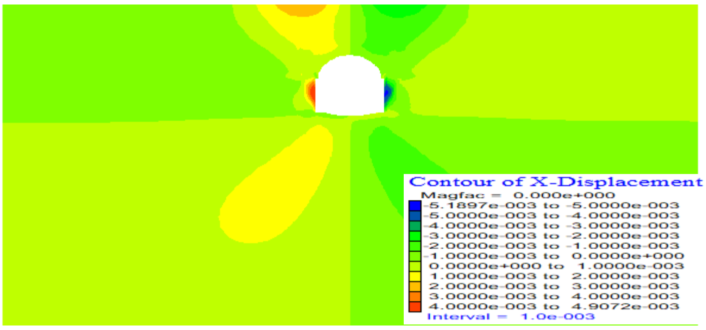


Figure 5.5 Displacement cloud map in X direction

According to the range analysis in Table 5.2, it can be seen that the sensitivity of the supporting parameters of the high side wall, the settlement value of the vault and the clearance convergence value of the high side wall in the subway station varies from large to small as follows[57]: diameter of steel tube piles *D*, spacing of steel tube piles *S*, spacing of prestressed anchor cables *s*, and length of prestressed anchor cables *l*.

However, the range analysis alone cannot distinguish whether the differences between the test results are caused by different factors or by test errors. Therefore, in order to find out the factors that affect the clearance convergence of the high side wall and the settlement of the vault more accurately, the variance analysis should also be carried out on the test results. In order to judge whether the factors considered have a significant impact on the test indicators, variance analysis was conducted for *a* and *b* respectively, as shown in Table 5.3 and 5.4. According to the data from the two tables, the pile diameter of steel pipe piles still has the greatest influence on the convergent displacement of the high side wall and the settlement value of the vault.

Table 5.3 Variance analysis of the settlement value a of the vault

Factor	Anchor length	Pile spacing	Anchor spacing	Pile diameter	Error
DevSq	1.639	0.233	1.505	13.0	0.88
DOF	4	4	4	4	0.88
Ratio of F	0.133	0.934	0.858	7.41	0.88
The critical value of F	3.84	3.84	3.84	3.84	0.88

Table 5.4 Variance analysis of convergence value b of high side wall

Factor	Anchor length	Pile spacing	Anchor spacing	Pile diameter	Error
DevSq	0.904	5.434	5.184	44.391	0.22
DOF	4	4	4	4	0.22
Ratio of F	0.158	0.948	0.904	7.745	0.22
The critical value of F	3.84	3.84	3.84	3.84	0.22

Based on the influence law of supporting parameters of high side wall on the settlement of station vault and the convergence of high side wall obtained from orthogonal test, the fitting regression of the obtained test data was carried out through Origin to determine the corresponding regression model[58-59].

It is easy to know from the test data that the relevant displacement of the station is proportional to the spacing between the steel pipe pile and the prestressed anchor cable, and inversely proportional to the diameter of the prestressed anchor cable and the steel pipe pile. Regression models $a（l，S，s，D）$ and $b（l，S，s，D）$ were respectively represented by

$g_1(x)$ and $g_2(x)$. The fitting results are shown in Table 5.5. Then Origin is used to draw a comparison diagram between the fitting curve and the test curve. The maximum error rate of the curve after fitting is calculated as 6.4%, as shown in Figure 5.6 and 5.7.

The regression model of the settlement value a of the vault is:

$$g_1(x) = m_1 + m_2 s^2 + m_3 s + m_4 l^2 + m_5 (\frac{1}{D})^2 + m_6 S^2 + m_7 S \quad (5.8)$$

The regression model of the convergence value b of the high side wall is:

$$g_2(x) = m_1 + m_2 s + m_3 l^2 + m_4 l + m_5 (\frac{1}{D})^2 + \frac{m_6}{D} + m_7 S \quad (5.9)$$

Table 5.5 Regression coefficients table

Survey line	m_1	m_2	m_3	m_4	m_5	m_6	m_7
a	12.79	-0.62	1.932	116.48	169.07	-0.0001	-0.008
b	1.927	1.073	-2471.56	258.51	201.44	-0.027	-0.09

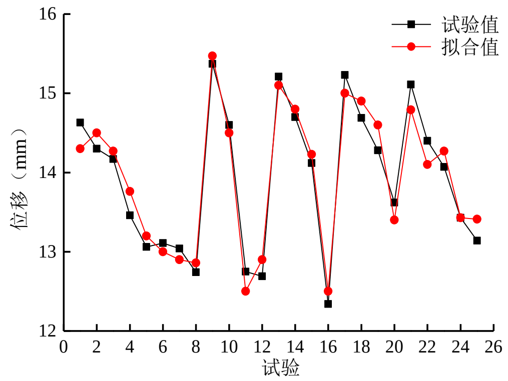


Figure 5.6 Displacement fitting curve of vault settlement value

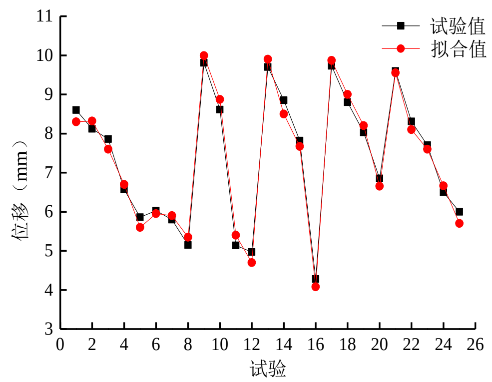


Figure 5.7 Displacement fitting curve of high side wall

The above four supporting parameters were taken as design variables, namely, spacing of steel tube piles S, diameter of steel tube piles D, length of prestressed anchor cables l, spacing of prestressed anchor cables s. Then the objective function is designed to predict the supporting cost formula of the position of the high side wall in the subway station under different supporting conditions. The design variables should meet the requirements of $g_1(x)$<14mm and $g_2(x)$<7mm. The minimum value of $f(x)$ under the above conditions is the final optimization scheme. The original design value of the project is: the length of prestressed anchor cable is 10m, the spacing of steel pipe piles is 1m, the spacing of prestressed anchor cable is 1.5m, and the diameter of steel pipe piles is 25cm.

The prediction calculation formula of support cost of subway station is[60-63]:

$$f(x)=\left[\frac{40a\pi}{x_3}\rho_1 x_1 c^2+\frac{20b\pi}{x_2}\rho_2(\frac{x_4}{100})^2\right] \tag{5.10}$$

In formula, a is the price of unit mass of each bolt and a is equal to 100; b is the price per unit mass of each steel pipe pile and b is equal to 50 ¥; c is the diameter of anchor bolt and c is equal to 0.03m; x_1 is anchor length; x_2 is pile spacing; x_3 is anchor spacing; x_4 is pile diameter; ρ_1 is anchor density, it is equal to 6000 kg/m^3; ρ_2 is density of steel pipe pile, it is equal to 3000kg/m^3.

Since the population number of particles (N) and inertia weight factor (w) will have an impact on the convergence rate. Fixed w=0.3, N=40, 50 and 60 are respectively selected for optimization. As can be seen from Fig 5.8, when the population number is 60, the adaptive value converges faster, so take N=60. Fixed N=50, the convergence rate of the algorithm under different w values is compared in Fig 5.9. The result shows that the convergence rate is faster when w satisfies formula (5.3).

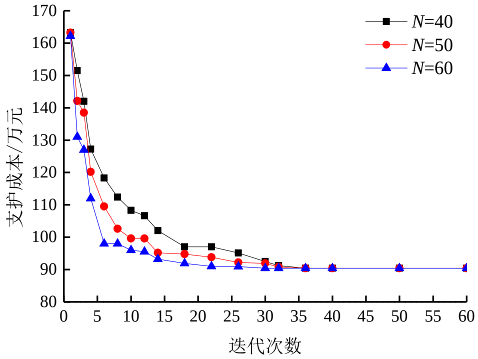


Figure 5.8 Convergence curve of fitness with different N

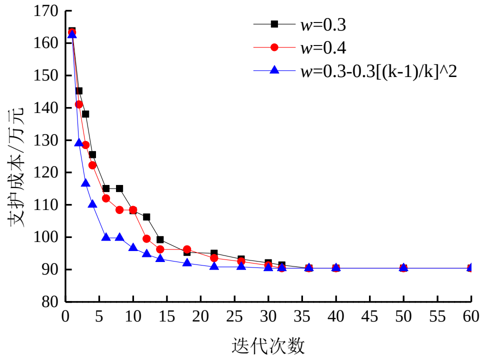


Figure 5.9 Convergence curve of fitness with different w

The results show that the convergence rate is the fastest when the population size number N is 60 and w satisfies Equation (5.3). When the program is substituted for optimization calculation, the length of prestressed anchor cable is 9.81m, the spacing of prestressed anchor cable is 1.48m, the spacing of prestressed anchor cable is 1.82m, and the diameter of steel pipe pile is 28.56cm. Figure 5.10 shows the changes of the four parameters searched by the PSO algorithm with the number of iterations. It can be seen that at the beginning of iteration, these parameters are far away from the optimal solution and fluctuate. With the increase of iteration step size, when the number of iterations reaches 30, these parameters tend to the optimal solution and remain stable. The results show that the optimal solution is obtained after 30 iterations with good convergence.

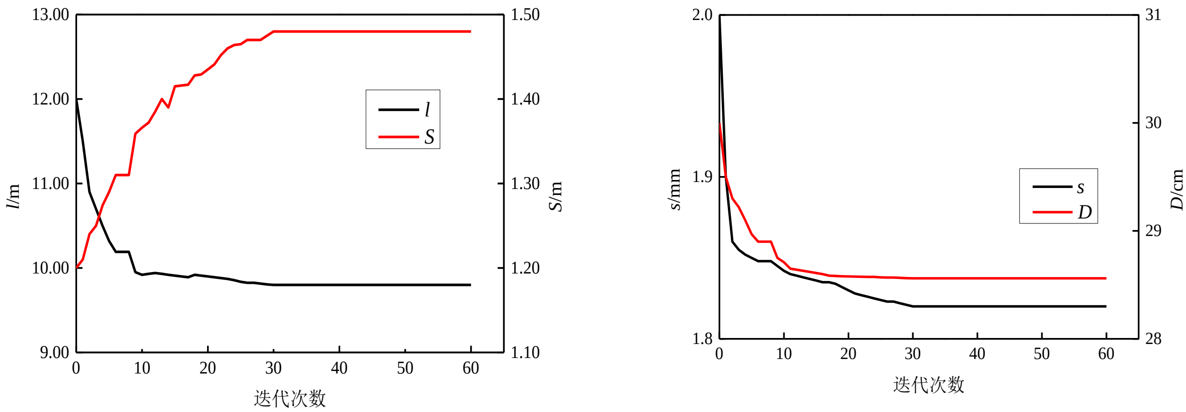


Figure 5.10 Parametric convergence curve

The convergence curve of fitness value function is shown in Figure 5.11. Similarly, when the number of iterations reaches 30, the adaptive value tends to be stable.

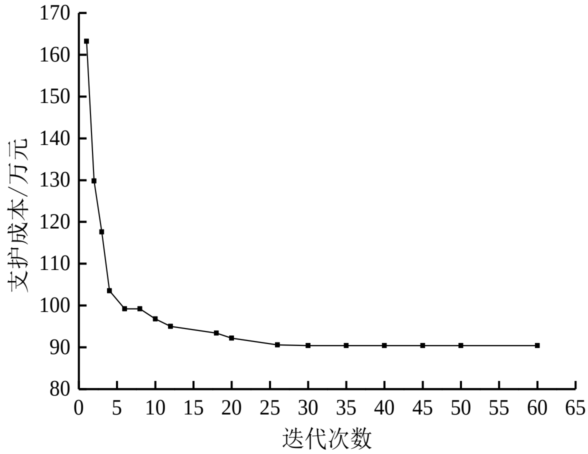


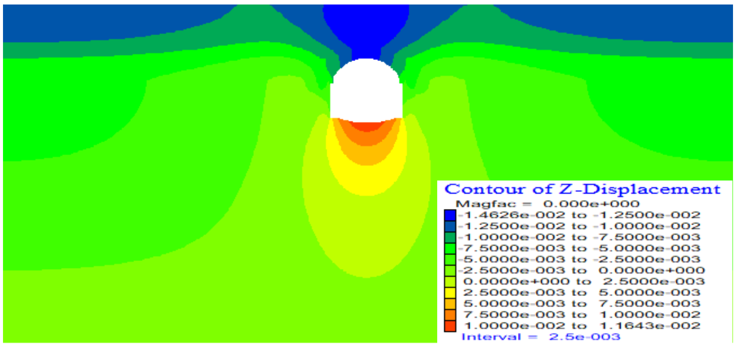
Figure 5.11 Convergence curve of fitness

Considering the actual demand of the project, the supporting parameters of the high side wall are difficult to reach the accuracy of the optimized value obtained by the program, so the length of the prestressed anchor cable is designed to be 10m, the spacing of the steel pipe pile is 1.5m, the spacing of the prestressed anchor cable is 2m, and the diameter of the steel pipe pile is 30cm. The optimization value, the original design value and the scheme meeting the displacement variation requirements of fitting displacement function in the orthogonal test were compared for the support cost, as shown in Table 5.6.

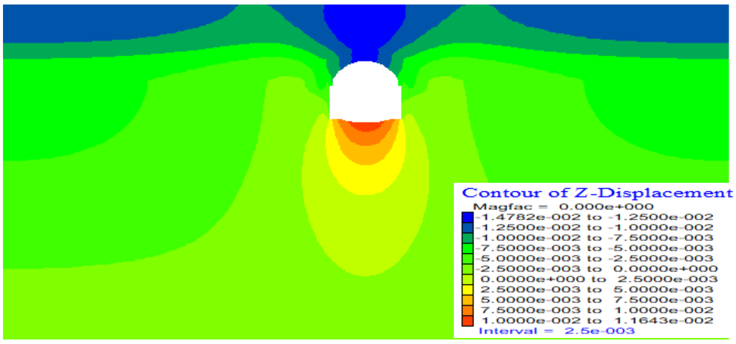
Table 5.6 Comparison of optimization schemes

	l(m)	*S*(m)	*s*(m)	*D*(cm)	a(mm)	b(mm)	Cost(元)
Optimal value	10	1.5	2	30	13.94	6.9	904320
Original design value	10	1	1.5	25	13.74	6.75	1040910
Test 4	8	1.2	1.8	30	13.46	6.57	1686180
Test 20	11	1.5	1.5	30	13.62	6.85	1062576

From the data in Table 5.6, it can be seen that the original design cost is 1.041 million yuan, while the optimized cost is 904,000 yuan, a decrease of 13.16%. By comparing the experimental 4 and 20 that meet the displacement requirements in the orthogonal test with the optimized value, the optimized construction parameter scheme of high side wall has significant advantages in the support cost. At the same time, the scheme also meets the requirements of displacement variation.



（a）Original test



（b）Optimal test

Figure 5.12 Vertical displacement comparison diagram between the optimized scheme and the original scheme

Vertical displacement nephograms of the optimized scheme and the original scheme are compared, as shown in Figure 5.12. As can be seen from the figure, the vertical displacement of the station after optimization increases slightly, but it is still within the stable range, indicating that the optimized construction parameter scheme of the high side wall is feasible.

5.4.2. Anchorage parameter optimization of main guide tunnel

At the same time, this optimization method can also be applied to the anchoring parameter optimization of the main guide tunnel of Qingniwa Bridge Station of Dalian Metro Line 5[64-68]. The geometric model size is 70m*60m*42m, and the guide hole information is as follows: The length of the guide tunnel is 60m, the height of the guide tunnel is 5.5m, the arch radius of the guide tunnel is 3m, and the buried depth of the guide tunnel is 18m. Combined with the above engineering information, the modeling is carried out. The constitutive relation of surrounding rock material is adopted by Mohr-Coulomb model, and the unit type is three-dimensional eight-node Block Group, and the number of units is 139200. Shell-type structural unit is used for the lining of the guide tunnel, and cable structural unit is used for the anchor rod. The surrounding rock is of grade V, with an elastic modulus of 1.5GPa, Poisson's ratio of 0.37, an internal friction Angle of 25° and a cohesive force of 0.17MPa. The calculation model is shown in Figure 5.13, and the material parameters of surrounding rock and supporting structure in actual engineering are shown in Table 5.7.

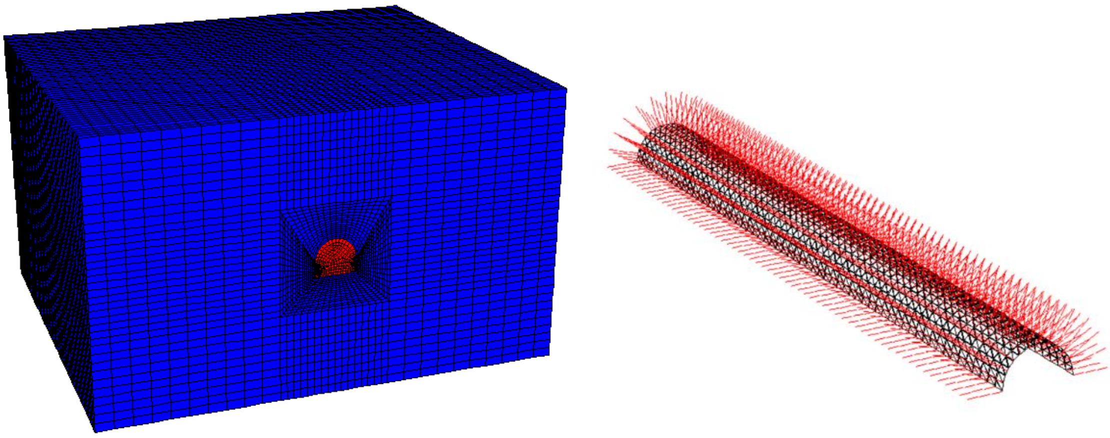


Figure 5.13 Numerical model

Table 5.7 Table of surrounding rock and support parameters

Type	Elastic modulus /GPa	Poisson's ratio	Density /(kg·m^{-3})	Internal friction angle /(°)	Cohesive force /(MPa)
Surrounding rock	1.5	0.37	2200	25	0.17
Concrete	21	0.2	2200	31.82	0.24
Anchor	210	---	6000	---	---

The cross section of the guide tunnel is shown in Figure 5.14, where point A represents the vault, and point B and C represent the waist of the arch.

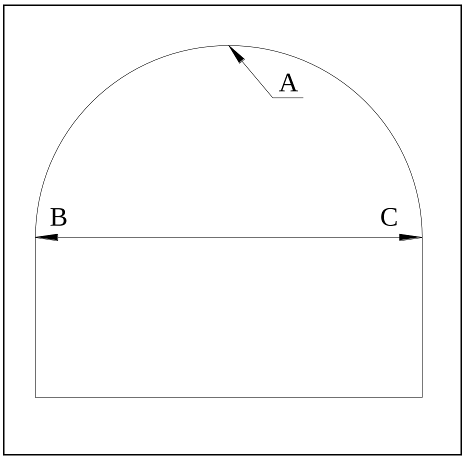


Figure 5.14 Section of the pilot tunnel

The test factors in this paper are: anchor length (*l*), anchor spacing (*s*), anchor diameter (*d*), the thick-ness of spray layer (*D*) and the elastic modulus of spray layer (*E*). The anchor spacing refers to the anchor spacing along the tunnel direction in each ring. The research scope of these five parameters was designed. They are as follows: *l* form 3.0 m to 4.0 m, *s* from 0.8 m to 1.2 m, *d* from 21 mm to 25 mm, *D* from 22 cm to 26 cm, *E* from 20 GPa to 24 GPa.

The settlement displacement *a* of the vault and the convergence displacement *b* of the waist of the arch are calculated by using Flac^{3D} calculation simulation. The parameters of the 25 schemes were put into the numerical model of the guide tunnel for numerical calculation, and then range analysis was conducted according to the calculated results to obtain range values of different parameters. The range analysis results are shown in Figure 5.15.

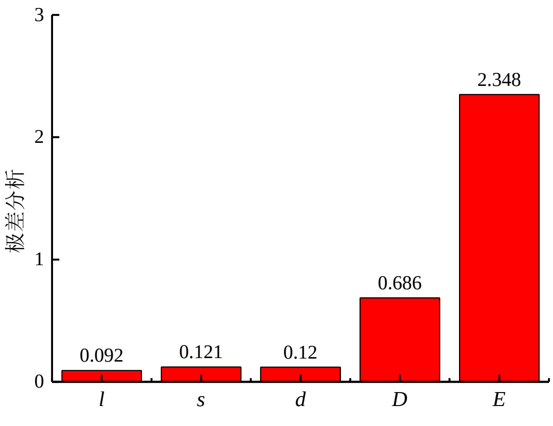


Figure 5.15 Sensitivity analysis diagram of anchoring parameters

According to Figure 5.15, the sensitivity of the settlement of the arch crown and the convergence of the arch waist are in descending order[69-70]: *E*, *D*, *s*, *d* and *l*. It is concluded that the elastic modulus of spray layer (*E*) is the most sensitive to the stability of surrounding rock, followed by the thickness of spray layer (*D*), the longitudinal spacing of anchor and the diameter length of anchor has little influence on the sensitivity of tunnel displacement.

According to relevant data, relevant displacement change of tunnel is inversely proportional to anchor length, anchor diameter, the thickness of spray layer and elastic modulus of spray layer, and directly proportional to anchor spacing. The following regression models *a* (*l*, *s*, *d*, *D*, *E*) and *b* (*l*, *s*, *d*, *D*, *E*) are respectively expressed by $g_1(x)$ and $g_2(x)$. The calculated results are shown in Tab.5, and then the comparison diagram between the fitting curve and the test curve was drawn with Origin. The maximum error rate of the fitted curve is calculated to be 8.33%, as shown in Figure 5.17 and 5.18. The error of the two curves is within the allowable range.

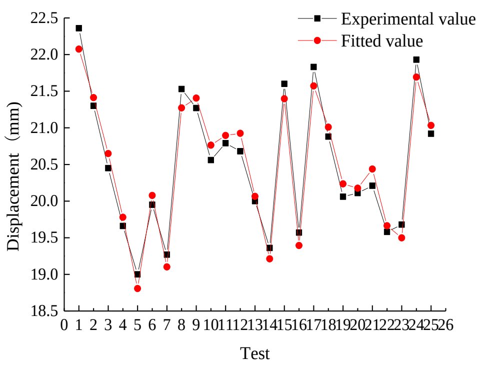


Figure 5.17 Displacement curve of the arch crown

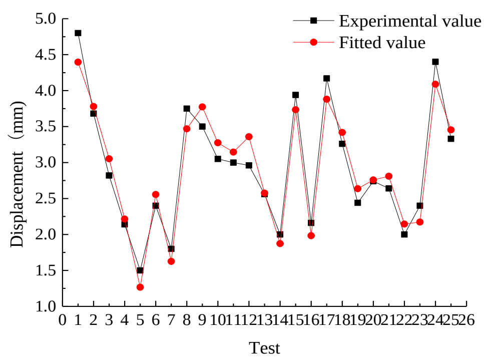


Figure 5.18 Displacement curve of the arch waist

Regression model of vault displacement a:

$$g_1(x) = m_1 + m_2 \frac{1}{l} + m_3 s^2 + m_4 s + m_5 \left(\frac{d}{1000}\right)^2 + m_6 \left(\frac{D}{10}\right)^2 + m_7 (E-16)^2 \qquad (5.10)$$

The regression model of the arch waist convergence displacement b:

$$g_2(x) = m_1 + m_2 \frac{1}{l} + m_3 s + m_4 \frac{1}{d} + m_5 \left(\frac{D}{10}\right)^2 + m_6 D + m_7 (E-16)^2 \qquad (5.11)$$

The objective function $f(X)$ is designed to predict the cost formula of the excavated tunnel section under different supporting conditions. The design variables should meet the following requirements. $g_1(X) \le 20mm$, $g_2(X) \le 3mm$. The calculation formula of the single side support cost is:

$$f(X)=\left[\mathrm{ab}\frac{\pi}{4}\rho(\frac{x_3}{1000})^2 x_1+(10x_5-200+\mathrm{c})x_4\right]/x_2 \tag{5.12}$$

In formula, a is the number of anchor roots in section, and a is equal to 22; b is the price per unit mass of each anchor, and b is equal to 100 ¥; c is the cost required for each centimeter of spray layer, and c is equal to 280 ¥; x_1 is anchor length; x_2 is anchor spacing; x_3 is anchor diameter; x_4 is the thickness of spray layer; x_5 is the elastic modulus of spray layer; ρ is anchor density, it is equal to 6000 kg/m^3.

After running the program, the optimized parameters are: x_1 =3m, x_2 =1.42m, x_3 =21.5mm, x_4 =24.6cm, x_5 =23.5GPa. But in practical engineering, it is difficult to make the parameters reach the precision of the optimal value. According to the actual use requirements of the project, the length of the bolt can be designed as 3m, the spacing of the bolt is designed as 1.4m, the diameter of the bolt is designed as 21mm, the thickness of the shotcrete is designed as 24cm, and the elastic modulus of the shotcrete is designed as 24GPa. The original design value was compared with the optimal value and the scheme meeting the requirements of design variables, and the results were shown in Table 5.8.

Table 5.8 Comparison of optimization schemes

	l/(m)	*s*/(m)	*d*/(mm)	*D*/(cm)	*E*/（GPa）	*a*/(mm)	*b*/(mm)	*Cost*/（¥）
The optimal value	3	1.42	21.5	24.6	23.5	19.47	2	14950
The original design value	3	1.2	22	26	21	20.96	3.2	18821
Test 6	3.2	1.2	22	24	23	19.95	2.4	19574
Test 23	4.0	1.0	22	22	24	19.69	2.4	27101
Final design value	3	1.4	21	24	24	19.46	2	15172

According to the data in Table 5.8, the original design cost required 18,821 yuan, while the support cost required after optimization was 15,172 yuan, a decrease of 19.4%. Then take the test 6 and test 23 which meet the displacement requirements in the orthogonal test and compare with the optimal value, the optimal value has a significant advantage in the support cost, and the scheme meets the displacement requirements and is more feasible.

5.5. *Subway station construction parameter optimization module*

(1) Module building ideas

Based on this section describes the method of particle swarm algorithm to optimize model arch cover subway station informatization construction management analysis system of subway station construction parameter optimization module, using the module to complete the construction parameters information import, numerical model shows that, the optimization algorithm and the optimization model for integration, support scheme design, the specific module operating model as shown in Figure 5.18.

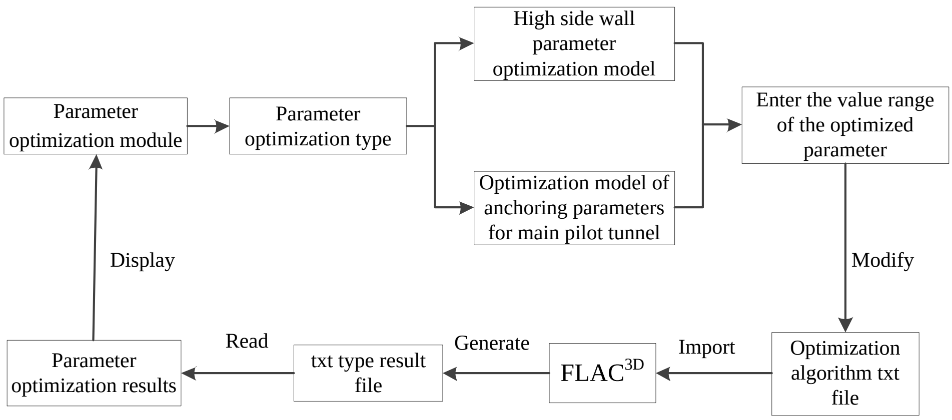


Figure 5.18 Operation flow chart of parameter optimization module

(2) Module establishment

Mainly around the txt file to read write, modify, and call the three aspects, for C++ language file action mainly use the document flow ", first of all need to read and modify txt file, the first is to specify the txt file to read, this module design to the two different types of optimization model corresponding to two txt file, therefore, This module uses the fread function to read the file path; Then, the specified position in the file needs to be modified. The modified position in the file is positioned through fseek function, and the modified content is the parameter optimization range. Finally, the parameters specified in the file are replaced by the fwrite function.

(3) Module realization and function introduction

Module is first to choose the type of optimization parameters, the system will automatically get this kind of construction parameter optimization model of particle swarm optimization calculation file, as shown in Figure 5.19 for optimizing the choice of parameters of the module interface, the input of the project scope of the original design of supporting parameters, system parameter information will be transferred to the particle swarm optimization algorithm based on FISH language code. Module to realize the information to modify the relevant parameters of the command flow, finally click button parameter optimization, the system will automatically call the background based on particle swarm optimization algorithm of parameters optimization of subway station construction, and the result of the generated txt file parameter selection information extraction, formed under the condition of displacement change security plan, cost minimum supporting parameters And is displayed in this module. As shown in Figure 5.20, it is the interface for generating the optimization scheme.

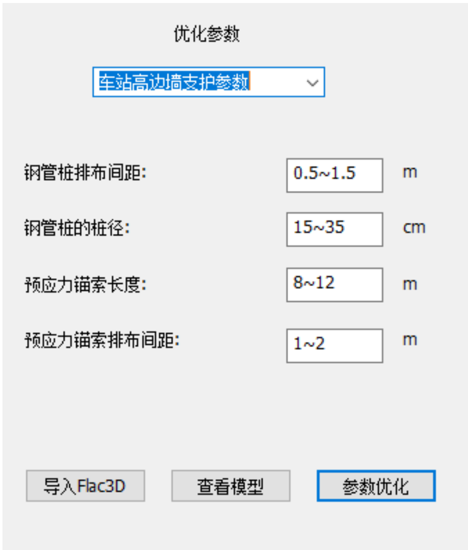


Figure 5.19 Input of parameters to be optimized

参数	参数优化结果	单位
钢管桩排布间距	1.48	m
钢管桩的桩径	28.56	cm
预应力锚索长度	9.81	m
预应力锚索排布间距	1.82	m

Figure 5.20 Generation of optimization scheme

5.6. Chapter summary

This paper, based on the principle of particle swarm optimization algorithm, the subway station construction parameter optimization model is established and developed the arch cover subway station construction parameter optimization module, the module by calling the particle swarm optimization based on FISH language program to realize high wall of the station position of supporting parameters and the main body of pilot tunnel anchorage parameters optimization design, Finally, when the length of prestressed anchor cable, the spacing of steel pipe piles, the spacing of prestressed anchor cable, the spacing of steel pipe piles and the distance of steel pipe piles are taken as 1.5m, 2m and 30cm to support the high side wall, the support cost is reduced by 13.16% and the displacement safety requirements are met. When the bolt spacing at the main guide hole is 1.4m, the bolt diameter is 21mm, the thickness of shotcrete is 24cm, and the elastic modulus of shotcrete is 24GPa, the support cost is reduced by 19.4%, and the displacement safety requirements are met.

6. Integrated development and implementation of management analysis system

6.1. Introduction

The monitoring information management module, risk comprehensive evaluation module and construction parameter optimization module in the first few chapters of the paper are realized through the developed computer software platform. In the first few chapters, the development and application of the main functional modules are introduced in detail. In this chapter, the integration technology including each module and the implementation of the computer software system are introduced. It should be pointed out that in order to increase the visualization effect of the program, the geographic information technology is also introduced on the basis of the core functions, including positioning and roaming functions, and the optimization algorithm of construction mound transportation path is added. Finally, the development of the system and its application interface are introduced.

6.2. Program realization

The implementation of the program first needs to modify the environment variables and configuration path of the system according to the instructions in the second chapter. In Microsoft Visual Studio 2010, the MFC window program based on C++ language was created and named as the construction management analysis system of the information construction of the subway station under the arch method. Then, the interface and function development of monitoring information management module, risk comprehensive evaluation module, construction parameter optimization module and other functional modules of the arch cover subway station are respectively made. Finally, all modules are integrated into the system and used by clicking buttons in the menu bar of the system.

6.2.1. System function menu

The main interface of the informationized construction management and analysis system of the arch cover subway station is mainly composed of menu bar, main window, status bar and external program interface. The Ribbon editor in the MFC program is used to design the menu bar of the system, and the development of the system function menu interface is completed.

(1) Menu bar

The system menu bar mainly includes the risk analysis module, monitoring information query and parameter optimization module, as well as some expansion modules, such as changing the system viewpoint, transportation path optimization, aircraft roaming, global positioning system, etc.

Figure 6.1 System menu bar

(2) Main window

The main window is mainly responsible for the visual display of 3D digital earth, high-definition satellite images and 3D solid models. The interface can automatically identify the position of the mouse in the 3D digital earth, perform ray intersection of mouse clicks, and realize the direct interaction between the 3D earth and users by clicking and dragging the mouse. In addition, the Windows of the function modules of monitoring information inquiry, risk assessment and construction parameter optimization in the menu bar will be displayed in the main window area.

(3) Status bar

The status bar is used to display the title of the form and the current date and time of the system.

(4) External program interface

The interface mainly includes the calculation of some numerical models, optimization algorithms of support parameters and the operation of path optimization algorithms.

6.2.2. Metro station monitoring information management module

The automatic monitoring data collected on site were sorted out and merged in the SQL Sever database to form a QNW.MDF file and stored in the database. The database file includes the monitoring data table of earth pressure box, reinforcement gauge, laser rangefinder and strain gauge. Through the ADO.NET interface, the metro station monitoring information management module in the system is connected to the database file. The specific implementation method has been introduced in the second chapter, and will not be explained here.

The monitoring information management module of subway station[71] includes two parts: the automatic monitoring data query of various sensors in subway station and the drawing of monitoring data curve, which can realize the management and analysis of the monitoring information in the arch method subway station.

1、Automatic monitoring data query

Conditional query includes sensor type and measuring point number. The sensor information and data can be searched by setting the monitoring date. This part is viewed in the form of a list.

2、Monitoring data curve drawing

Curve drawing shares the same editing box and query conditions with monitoring data query. By selecting line chart in the monitoring data information management module, curve drawing of monitoring data of one or more sensors can be conducted. Figure 6.2 shows the interface of monitoring information management module.

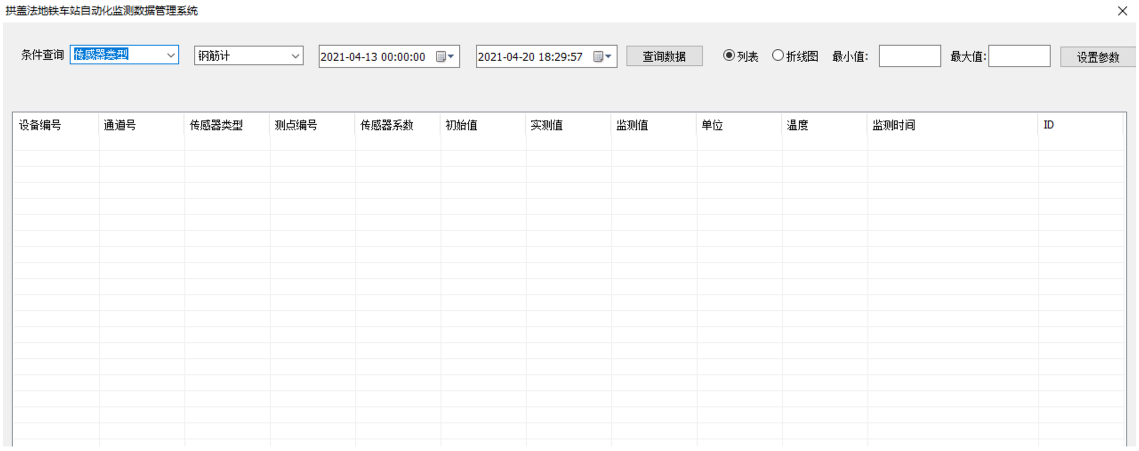


Figure 6.2 Monitor information management module interface

6.2.3. *Comprehensive evaluation module of subway station risk*

System through C++ language Settings button click trigger events into the subway station risk comprehensive evaluation module, the module and system share the same database, the database can be from the level of risk evaluation, risk characteristics and other information query, and enter the weight of each risk to calculate program, complete the module integration work. Figure 6.3 shows the interface of risk comprehensive evaluation module of subway station.

Figure 6.3 Subway station risk comprehensive evaluation module interface

The comprehensive risk evaluation module of subway stations[72-73] provides operations such as inquiry of risk evaluation indexes and risk scoring in subway stations constructed by arch cover method. Click the risk evaluation button on the main interface of the system to automatically pop up the interface of the comprehensive risk evaluation module of subway station. Users can display and view the risk factor evaluation indexes in the specified criterion layer and index layer through conditional query operation. The risk scoring area is corresponding to the risk evaluation indexes of the risk factors of subway station with the arch cover method. Users can manually input the risk occurrence probability and risk hazard degree of each risk factor in the risk index section, and finally click the calculation system to automatically calculate the total risk score according to the weight of each risk, so as to realize the risk evaluation of subway stations.

6.2.4. Metro station construction parameter optimization module

By reading the database information of the system, the module switches the optimization model of the supporting parameters of the high side wall and the anchoring parameters of the main guide tunnel of the subway station in the construction design. The module is also provided with a model viewing interface. Click the "View Model" button to read and display the model structure of the construction parameters selected by the user. For parameter optimization, this module is mainly through the external call particle swarm optimization based on FISH language program to implement, the module of the edit field enter the corresponding optimization parameter values range, click import Flac^{3D}, the corresponding position of the optimizer is modified and automatic generation into the software to calculate, finally produces the optimized parameter values, The support scheme with the lowest support cost is formed under the condition of ensuring safe deformation. As shown in Figure 6.4, the interface of optimization module for construction parameters of subway station is shown.

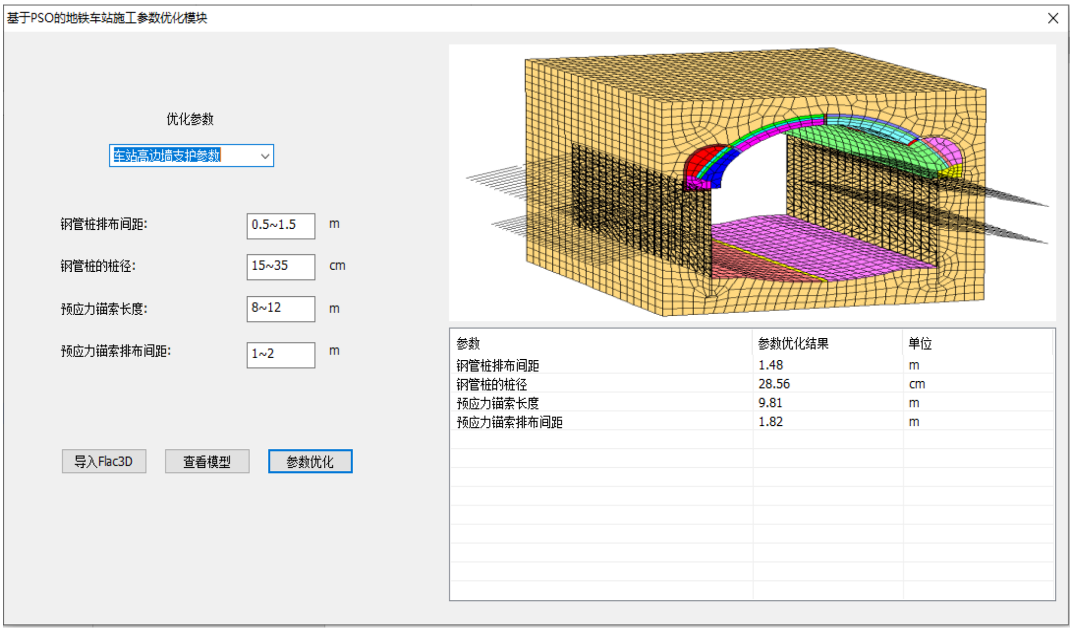


Figure 6.4 Subway station construction parameter optimization module interface

6.2.5. System expansion module

In addition to the above main modules, some extension modules are also developed. In order to improve the visualization effect of the system developed in this paper, GIS related technologies are introduced into the system to establish the global positioning system module. This module realizes the positioning and viewing of any latitude and longitude height in the world. At the same time, the intelligent optimization algorithm is integrated into the system to build the path optimization module in the system. The system can automatically identify the optimal path for the road network built by users.

(1) Global positioning system module

The positioning and roaming function[74] can carry out real-time positioning and viewing of any location with specified longitude and latitude coordinates and height in the world. The view Angle is a vertical view by default. This module is equipped with the input box of longitude, latitude and height. The view point of the 3D digital earth is automatically positioned to the specified longitude and latitude coordinates and height for inspection. As shown in Figure 6.5, the positioning effect of Dalian Railway Station, Qingniwa Bridge Station and Labor Park Station in Dalian Metro Line 5 is shown.

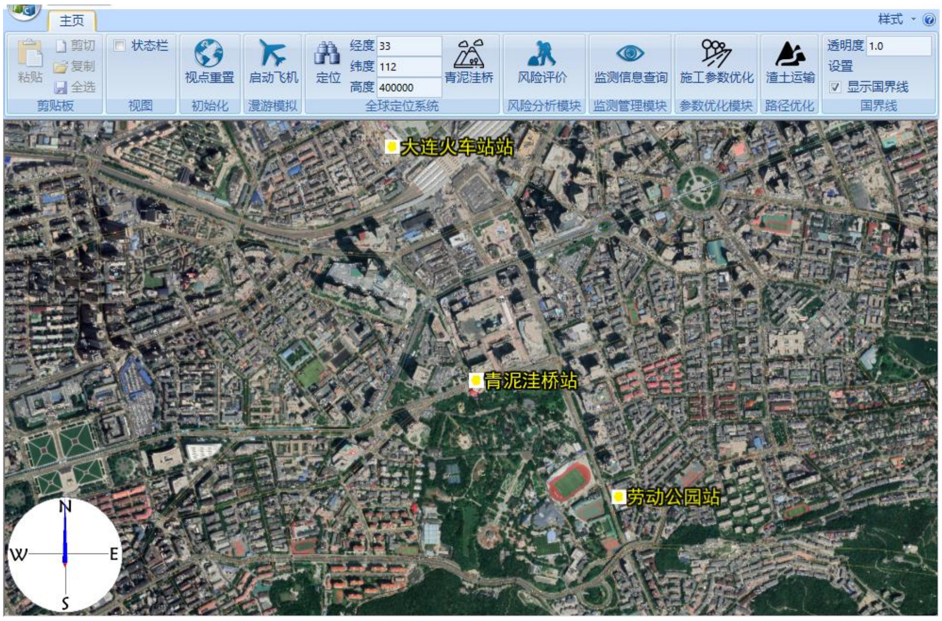


Figure 6.5 System positioning function effect drawing

The system realizes the roaming function of Qingniwa Bridge Station model of Dalian Metro Line 5. By clicking the viewing Angle roaming button, the roaming route set in the system is triggered, and the user's viewing Angle is led to move according to the specified path to observe the contour and structure of the station model. The roaming effect is shown in Figure 6.6.

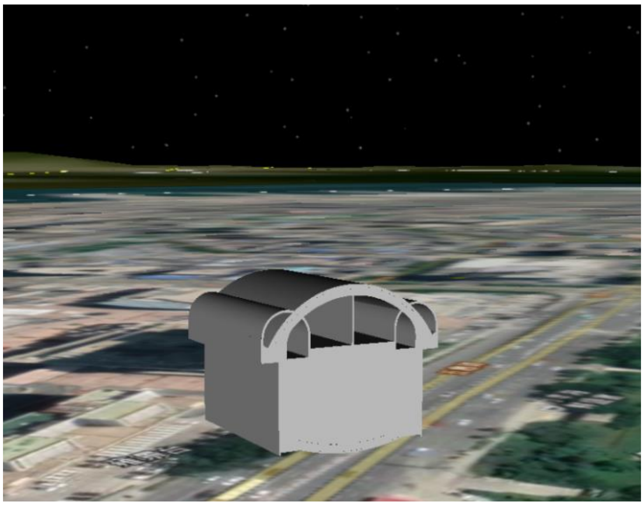


Figure 6.6 Virtual tour of the station effect

(2) Path optimization module

As a common function in GIS system, path optimization is mainly realized by designing the optimal path through optimization algorithm. A large amount of muck will be transported out every day in the construction of subway station. In order to improve the efficiency of muck transportation, this system has developed the muck transportation path optimization module[75-76]. This module integrates Dijkstra algorithm to optimize the path of the slag truck from the site to the slag dump.

Dijkstra's algorithm, also known as Dijkstra's algorithm[77], is an algorithm based on a greedy strategy. Its basic idea is to make the choices made appear to be the current optimal ones. Generate a global optimal solution. The basic idea of Dijkstra algorithm is: divide the set of nodes in the graph into two groups: one group is the node set S, and the weights of the shortest path from the source point s to the nodes in the set S have been determined; the other group is the rest of the nodes. Determine the shortest path node set Q. In the increasing order of the shortest path weight, the nodes in the set Q are added to S. During the joining process, the shortest path length from the source point s to each node in S is always kept not greater than any of the points from the source point s to Q The shortest path length of the node, the algorithm is to repeatedly select the node with the shortest path estimate and add u to S.

First, we must abstract the actual road network, and establish a corresponding road network model, that is, a network diagram, which is generally expressed through the data structure of "graph", and uses various graph algorithms in graph theory to study Its optimal path problem. A road network model can be constructed as follows:

$$\begin{cases} G = (V, E, W) \\ V = \{v_i \mid i = 1, 2, ..., n-1\} \\ E = \{< v_i, v_j > \mid v_i, v_j \in V\} \\ W = \{w_{ij} \mid < v_i, v_j > \in E\} \end{cases} \quad (6.1)$$

Among them, V represents the vertex set; E represents the road segment set, and road segments and are two different road segments; W represents the weight set of the road segment, and its attribute value can be selected according to different optimization goals.

For the actual urban road network, the traffic information in the two directions of the same road section is generally different, so a directed graph is used to express the actual road network.

The determination and calculation of right-of-way weight, also known as road traffic impedance or road resistance, is the basis of optimal path planning algorithm optimization goal, which generally consists of two parts: road weight and node weight. Road resistance is a measure of the cost paid by travelers in travel, and it is the main parameter for urban traffic planning, traffic flow allocation and route selection. According to whether road resistance changes over time, it can be divided into static road resistance and dynamic road resistance. Static road resistance includes section length, lane number, road type, road grade, lane function division, etc., while dynamic road resistance includes section speed, travel time, congestion degree, etc. In the optimal path planning, different road resistance can be selected according to the traveler's preference.

In the actual optimal path planning, various data in the road traffic network need to be stored. Among them, the most commonly used data storage structures are Adjacency Matrix, Adjacency List, Adjacency Multilist, and Orthogonal List.

As a special network, the urban road traffic network needs to consider some of its special properties compared with the general network. Its data storage structure and road network expression should meet the following conditions:

1、Can fully express the various elements and topological structure of the road traffic network;

2、The data storage structure is simple, the storage space is small, and the redundancy is small;

3、 Real-time information query in the road traffic network;

4、 Can fully express various traffic restriction information of the road network;

5、 Facilitate the operation of computer recognition and path planning algorithms.

The static shortest path research is earlier and has achieved more results, which has been put into use in many cities and regions. However, at present, there is no general algorithm that can be applied to all urban road traffic networks, and it can meet people's expectations in terms of time cost, space cost and ease of implementation. For large sparse graphs such as urban road traffic network, adjacency list has been proved to be the most effective data storage structure. Therefore, this paper adopts adjacency list to store traffic data related to the road network. The interface of path optimization program is shown in Figure 6.7.

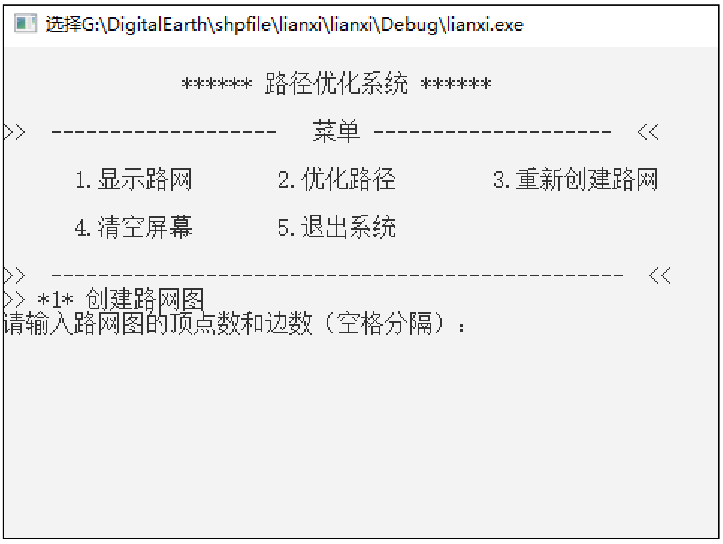


Figure 6.7 Path optimization program interface

Users enter the number of vertices and edges to create a road map, and then enter the right-of-way value between the two vertices. Click on the optimized path to get the optimal route. The right of way adopted in this paper takes the road length and the number of traffic lights as indicators. The conversion formula of the right of way with the road length and the number of traffic lights is as follows:

$$G = v \times t \times n + l \qquad (6.2)$$

In the formula, G is the road weight; v is the average speed of transport vehicles; t is the average waiting time for traffic lights; n is the number of traffic lights; l is the length of the road section.

6.3. Program application interface

6.3.1. Visualization of subway station model

Combined with the model reading function introduced in Section 2.4.4 of Chapter 2, this system can view the subway station model established by Revit software at the Qingniwa Bridge Station. Figure 6.8 shows the visual model of the subway station model.

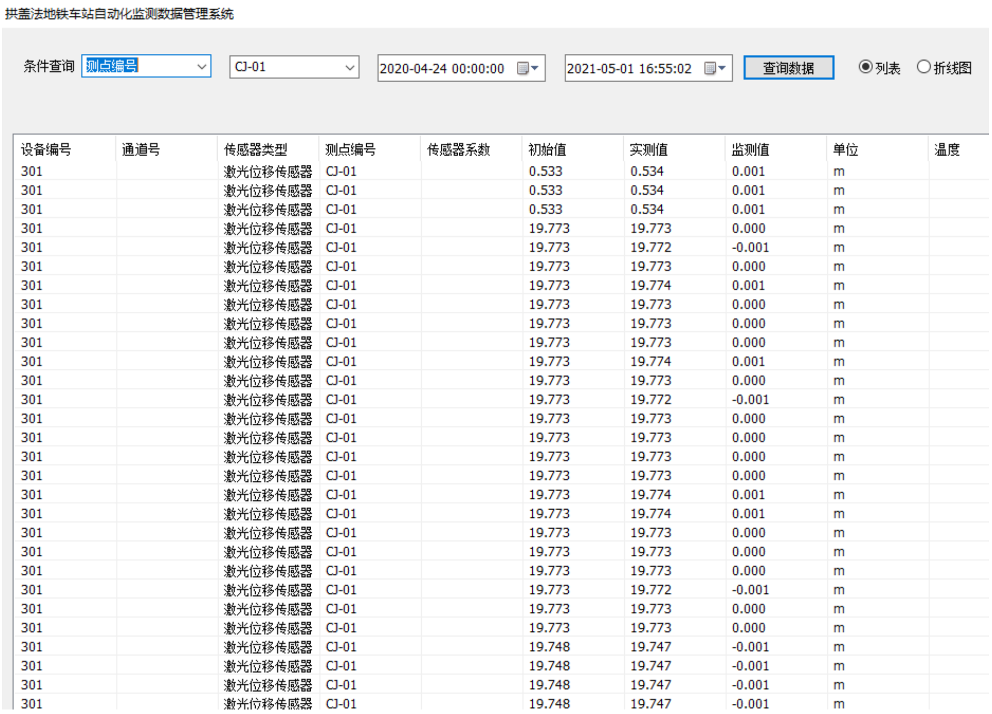
Figure 6.8 Visualized interface of subway station model

Combined with the model picking function introduced in Section 2.4.4 in Chapter 2, the system can directly click on the station model with the mouse, and automatically pop up the automated collection, analysis and management modules and risks introduced in Chapters 3, 4, and 5 of this paper. Comprehensive evaluation module and metro station construction parameter optimization module.

6.3.2. Metro station monitoring information management

The system applied the monitoring information management module of subway station, and realized the batch query and management of the monitoring data of typical section of Qingniwa Bridge Station of Dalian Metro Line 5, including the earth pressure value of the station, the stress value of steel arch, the strain value of the middle partition wall and the convergence value of the clearance of the high side wall.

Through the installation of monitoring sensor hardware in the field project, the monitoring data of the arch method subway station will be stored in the SQL database, and the system will check the collected monitoring data in batches by connecting to the local database. As shown in Figure 6.9, the list of monitoring data of the laser rangefinder CJ-01 for the position of the high side wall in the subway station is viewed.



设备编号	通道号	传感器类型	测点编号	传感器系数	初始值	实测值	监测值	单位	温度
301		激光位移传感器	CJ-01		0.533	0.534	0.001	m	
301		激光位移传感器	CJ-01		0.533	0.534	0.001	m	
301		激光位移传感器	CJ-01		0.533	0.534	0.001	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.772	-0.001	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.774	0.001	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.774	0.001	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.772	-0.001	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.774	0.001	m	
301		激光位移传感器	CJ-01		19.773	19.774	0.001	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.772	-0.001	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.773	19.773	0.000	m	
301		激光位移传感器	CJ-01		19.748	19.747	-0.001	m	
301		激光位移传感器	CJ-01		19.748	19.747	-0.001	m	
301		激光位移传感器	CJ-01		19.748	19.747	-0.001	m	
301		激光位移传感器	CJ-01		19.748	19.747	-0.001	m	

Figure 6.9 Monitoring data of laser rangefinder CJ-01

System can also draw a custom curve of sensor number and date of monitoring data, effectively saved monitoring data processing time and facilitate change trend analysis of the monitoring data, as shown in Figure 6.10 for laser rangefinder CJ - 01 monitoring data curve drawing a graph, for the analysis of the monitoring data of detailed in section 3.4 in the third chapter in this paper.

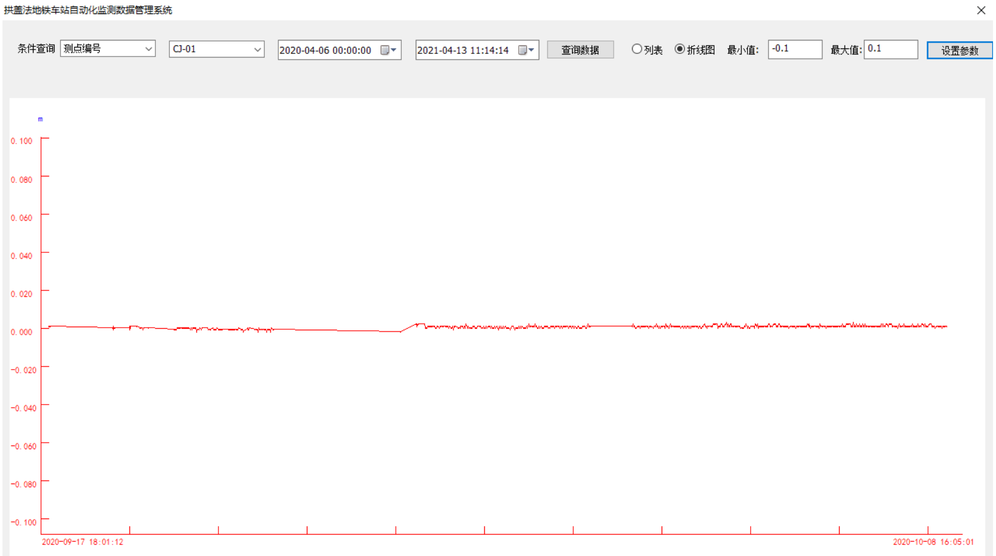


Figure 6.10 Laser rangefinder CJ-01 monitoring data curve changes

6.3.3. Multi-factor risk assessment of subway station

On Dalian Metro Line 5 blue mud hollow bridge station on risk comprehensive evaluation module in the system application, through monitoring risk, environment risk, and the construction of the subway station three aspects carries on the risk evaluation, risk analysis and risk assessment results to the risk of countermeasures, as shown in Figure 6.11 for green clay hollow bridge station risk assessment results.

风险分值

风险因素	风险发生概率（P）	风险危害程度（S）	风险权值（ω）	评价分（B）
地表沉降	2	3	0.120	0.720
拱顶沉降	2	3	0.068	0.408
初支净空收敛	2	3	0.029	0.174
初支钢筋轴力	1	2	0.013	0.026
地层岩性	3	2	0.013	0.078
地下水	4	3	0.022	0.264
邻近建筑物	4	2	0.041	0.328
地下管线	4	2	0.038	0.304
天气	2	2	0.007	0.028
爆破作业伤害	3	4	0.053	0.636
进尺长度过长	3	3	0.089	0.801
掌子面失稳	3	4	0.259	3.108
临时支撑拆除过长	3	3	0.089	0.801
超欠挖量过大	3	4	0.158	1.896

计算　总风险评分: 9.572

Figure 6.11 Risk analysis results of Qingniwa Bridge Station

The results show that the total risk level of subway station construction is three, which indicates that the risk is worth paying attention to and preventive measures need to be prepared, among which the environmental and construction risks in subway station are more obvious. The actual engineering results also show that the environmental conditions of the subway station are complicated and changeable, the stratum lithology is loose, and groundwater leakage often occurs. Therefore, in the construction of this project, blasting excavation should be reasonably controlled, and the frequency of monitoring and measurement should be strengthened at the same time. Construction parameters should be optimized for the location of the station with bad geology and large deformation and displacement. For specific risk countermeasures, please refer to Section 4.4 in Chapter 4 of this chapter.

6.3.4. Optimization of subway station construction parameters

System parameter optimization module used for subway station construction, by calling the Flac^{3D} finite difference software high sidewall of metro station location and dominate the hole point displacement is calculated, based on the orthogonal experiment method and establish the regression model, displacement by particle swarm optimization algorithm with the formula of supporting cost optimization model is set up, eventually forming optimization scheme, As shown in Figure 6.12, the anchorage parameter optimization interface of the station guide tunnel is presented.

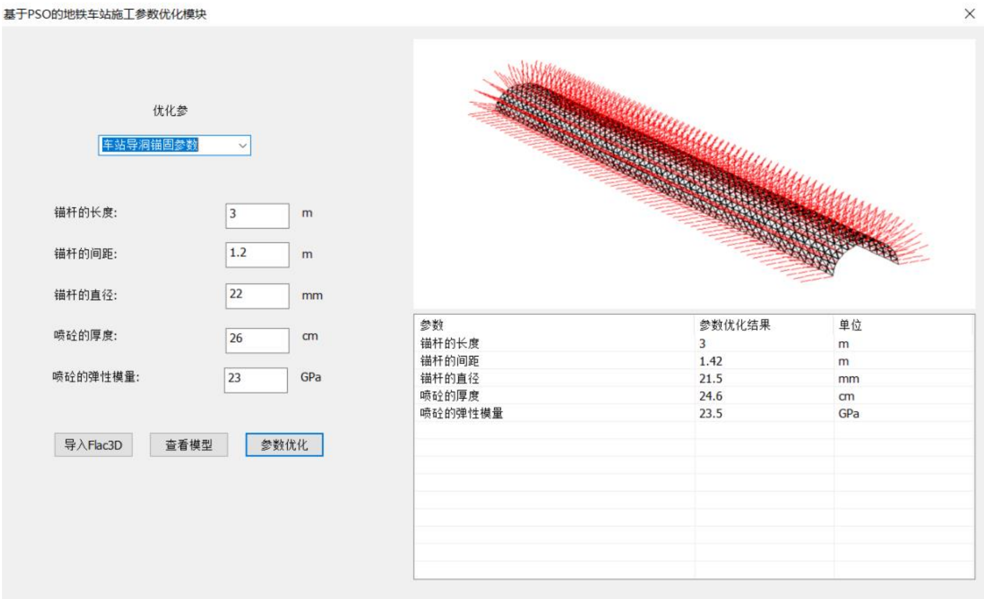


Figure 6.12 The anchorage parameter optimization interface of the station guide tunnel

Enter the original support scheme of the project and import it into Flac^{3D}. Click the "View Model" button to view the support structure and numerical model. Click the "Parameters Optimization" button and the program will automatically run and calculate, and the optimized scheme will be displayed in the edit box. The calculation results show that when the designed bolt length is 3m, bolt spacing is 1.42m, bolt diameter is 21.5mm, the thickness of shotcrete is 24.6cm, and the elastic modulus of shotcrete is 23.5GPa, the displacement safety requirements are met. Meanwhile, the support cost is reduced by 19.4% compared with the original engineering design scheme.

6.3.5. Optimization of muck transport path in metro station

For the subway station construction by arch method, a large amount of muck will be produced every day in the construction process due to the impact of blasting and excavation. In the way of excavating slag in Qingniwa Bridge Station of Dalian Metro Line 5, 50 type excavator is used to pick up the slag, and the slag is seized by 2.5m^3 grab bucket and lifted to the temporary slag dump site on the ground, and then transported to the designated slag dump site by earth truck. According to relevant engineering data, the starting point of slag truck in Qingniwa Bridge Metro Station project to transport muck every day is Qingniwa Bridge Station and the end point is Dalian Maosurzi Waste Treatment Plant. It is assumed that the average waiting time of traffic lights is 30s. The speed limit of Dalian transport vehicles is 60km/h, and the average speed of transport vehicles here is 45km/h. According to the high-definition layer displayed on the system's 3D digital earth platform, the specific positions of the two places were marked and the route was drawn. There were three design routes respectively:

1、Qingniwa Bridge Station -- Zhongshan Road -- Huanghe Road -- Northeast Expressway -- Yaojia Road -- Yingjin Road -- Bohai Road -- Dalian Maosurzi Garbage Disposal Plant

2、Qingniwa Bridge Station -- Zhongshan Road -- Yinghua Road -- Changjiang Road -- Donglian Road -- Yingjin Road -- Bohai Road -- Dalian Maosurzi Waste Disposal Plant

3、Qingniwa Bridge Station -- Zhongshan Road -- Yinghua Road -- Changjiang Road -- Donglian Road -- Gannan Road Bridge -- Yunling Street -- Bohai Road -- Dalian Maosuzi Garbage

Disposal Plant

Calculate the road weight according to Formula 6.2 and convert it into the corresponding road network structure diagram, as shown in Figure 6.13, where a -- b -- c -- d -- e is route (1), a -- h -- i -- j -- k -- e is route (2), and a -- b -- f -- g -- e is route (3).

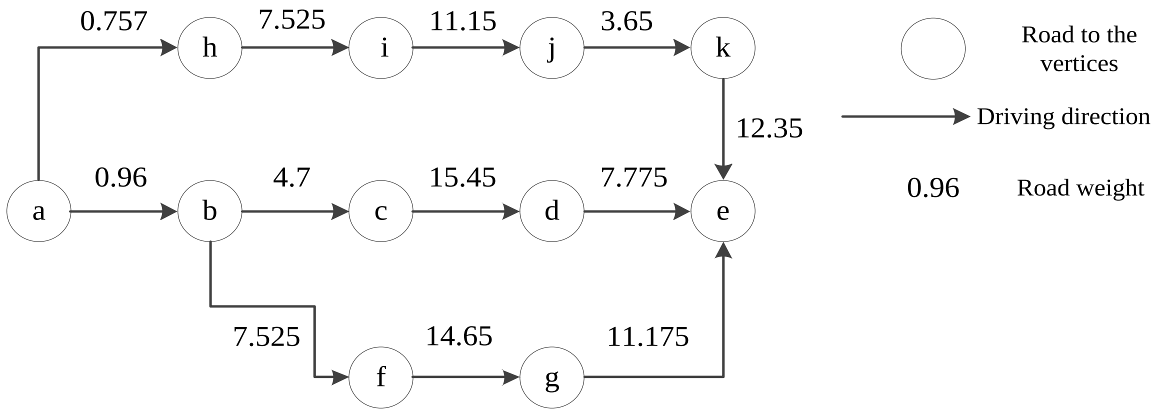


Figure 6.13 Road network structure diagram

The corresponding road length weight data of the road network was written into the program for calculation, and the shortest path was obtained as Qingniwa Bridge Station -- Zhongshan Road -- Huanghe Road -- Northeast Expressway -- Yaojia Road -- Yingjin Road -- Bohai Road -- Dalian Maosuzi Waste Treatment Plant. The optimized operation interface is shown in Figure 6.14. The roaming technology system mentioned in the previous section can also realize the transportation simulation effect of slag truck, as shown in Figure 6.15.

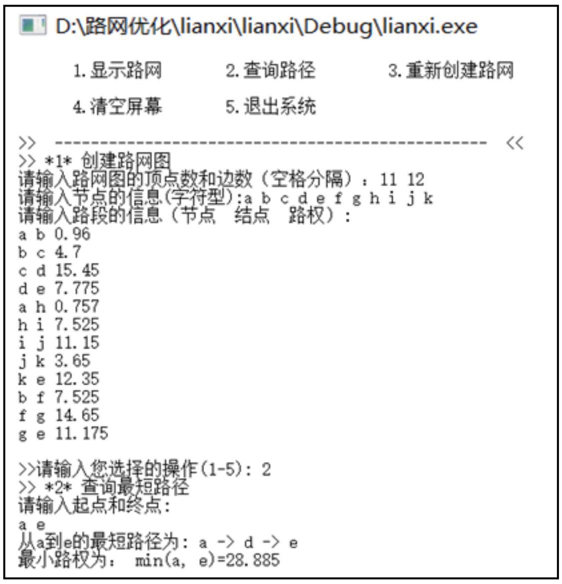


Figure 6.14 Optimize the operation interface

Figure 6.15 Vehicle transportation simulation diagram

6.4. Chapter summary

This chapter realizes the integration of the monitoring information management module, the risk comprehensive evaluation module and the construction parameter optimization module of the subway station, and introduces and demonstrates the expanded function module of the menu of the informationized construction management analysis system of the arch method subway station. Combined with the Qingniwa Bridge Station Project of Dalian Metro Line 5, this paper applied the "arch method metro station information construction management and analysis system" independently developed in this paper. Finally, the monitoring information of the project was managed, the risks in the station were controlled, and the construction parameters were optimized. At the same time, the system also integrates the path optimization module based on the intelligent algorithm to design the transportation path of the dregs generated in the construction of the subway station. The system provides scientific and efficient data support and technical support for the information construction of subway station.

7. Conclusion

Based on the research and analysis of the construction characteristics of the arch method subway station and the requirements of information management system, this paper developed the "Informationized Construction Management Analysis System of Metro Station with Arch Cover Method " under the platform of Visual Studio 2010 based on C++ language. It realizes the functions of monitoring information management, risk analysis, support parameter optimization and so on in the construction process of subway station. Finally, based on the project background of Qingniwa Bridge Station of Dalian Metro Line 5, this system is applied to further guide the construction. The main research conclusions are as follows:

（1） It is necessary to carry out multi-factor information monitoring, multi-factor risk analysis and parameter optimization in combination with the construction management characteristics of the arched metro station; The framework of integrated analysis system based on the above analysis technology is reasonable and feasible.

（2） according to the scene of the construction condition, the automatic monitoring of hardware is decorated, in combination with multivariate information monitoring and database technology to develop the arch cover subway station construction information automation management module, the module provides for automatic monitoring data query and curve drawing, implements the management of the construction monitoring data, and analysis of monitoring data, According to the analysis results, the construction suggestions of the middle door, the arch cover and the high side wall of the arch cover subway station are summarized, which can provide some help for the construction of the arch cover subway station.

（3） based on analytic hierarchy process (ahp) and fuzzy comprehensive evaluation technology developed arch cover risk analysis of multi-factor fuzzy evaluation method of the metro station module, the module integrates the method of arch cover subway station level 3 risk evaluation system, to realize quantitative evaluation of risk of subway station construction, finally it is concluded that the subway station construction risk value of secondary risk grades, including station excavation risk reached level 3, Risk valuation reached 11.178; Finally, relevant risk countermeasures are put forward to prevent the occurrence of dangerous accidents.

(4) based on the principle of particle swarm optimization algorithm, the subway station construction parameter optimization model is established, combined with this kind of parameter optimization method, developed the arch cover subway station construction parameter optimization module, the module by calling the particle swarm optimization based on FISH language program to realize high wall of the station position of supporting parameters and the main body of pilot tunnel anchorage parameters optimization design, Finally, when the length of prestressed anchor cable at the high side wall is 10m, the spacing of steel tube piles is 1.5m, the spacing of prestressed anchor cable is 2m, the diameter of steel tube pile is 30cm, and the spacing of anchor bolt at the main guide hole is 1.4m, the diameter of anchor bolt is 21mm, the thickness of shotcrete is 24cm, and the elastic modulus of shotcrete is 24GPa, the results show that the length of prestressed anchor cable at the high side wall is 10m, the spacing of steel tube piles is 1.5m, the spacing of steel tube piles is 2m, the diameter of anchor bolt is 21mm, the thickness of shotcrete is 24cm and the elastic modulus of shotcrete is 24GPa. The construction of subway station is within the safe range of displacement change, and the supporting cost is reduced by about 15% compared with the original scheme.

(5) by integrating the arch cover subway station monitoring data management, construction risk analysis and parameter optimization module, the paper successfully set up "the analysis method of arch cover subway station informatization construction management system", and implements the green clay hollow bridge subway station model visualization, localization, roaming and the construction of sediment transport path optimization, and other functions, in the end, The construction information of the project has been managed, the construction support scheme has been adjusted and optimized, and the construction risk has been controlled, which verifies the reliability of the system studied in this paper.

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