Research and application of automatic monitoring system for tunnel-surrounding rock measurement based on GIS

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Received: 12 March 2021 / Accepted: 27 April 2021 / Published online: 29 May 2021 © Saudi Society for Geosciences 2021

Abstract
This paper establishes a geological three-dimensional coordinate model and uses GIS to obtain the thickness of the overburden. The tunnel displacement monitoring points mainly include: vault settlement measurement points, foot settlement measurement points, and gap convergence measurement points. This paper constructs a GIS-based section tunnel entrance safety evaluation system, which provides a reference for the safety evaluation of the section tunnel entrance. The determination of the construction parameters and support parameters of the tunnel engineering is deeply affected by the stress conditions of the tunnel engineering. Under the conditions of limited economy and time, before tunnel construction, the mechanical parameters of the tunnel-surrounding rock are determined mainly through limited drilling. Although it is somewhat difficult, the construction parameters of tunnel engineering are also determined accordingly. The calculation results may cause the actual deformation of the surrounding rock to be quite different from the predicted deformation, and accidents may be caused according to the original construction plan. Therefore, the supervision and measurement of tunnel engineering is particularly important. At the same time, a risk evaluation system is established to achieve the control of risk evaluation indicators, which can intuitively express the size of the tunnel entrance affected by the evaluation factors, calculate the mechanical parameters of the surrounding rock of the tunnel, determine the construction parameters and support parameters of the tunnel project, and analyze the measured displacement changes to ensure long-term stable construction and support. Through the actual application of the project, it can be seen that the risk assessment system can also conveniently and quickly query and analyze the monitoring data of the tunnel, and it can realize online operation and analyze the stability of the surrounding rock. This proves the rationality of the planning and framework of the detection system, and it has high application value.

Keywords GIS · Automation · Tunnel-surrounding rock measurement · Monitoring system

Introduction
Under the strategic background of the large-scale development of western China, tunnel engineering has become a major research hotspot in western China. Monitoring and measurement is an indispensable step in the tunnel construction process and is of great significance (Adelaye and Fayose 1978). At the same time, it is also one of the three major elements of tunnel construction. However, the current monitoring and measurement of tunnel engineering is in most cases “on paper” and has not been applied in the actual construction process, so it has not been able to achieve the desired effect. Regarding the monitoring and measurement of tunnel engineering in the direction of construction, it is still not easy to ensure the safety of construction (Adetona and Abu 2013). Therefore, the study of tunnel construction monitoring measurement and the reverse application of monitoring data has important practical significance and research value (Adighije 1981). Tunnel construction is the key to the development of the railway, but the construction will destroy the original static balance of the surrounding rock of the tunnel and the overall internal balance. Before the excavation of the tunnel project, the rock mass where it is located is in the original stress state, that is, the rock mass is in a relatively stable stress environment. The surrounding rock will once again reach a new mechanical equilibrium state in the tunnel due to the supporting
effect of the supporting structure and the self-stabilization effect of the surrounding rock (Ajayi and Ajakaiye 1981). Therefore, a series of similar gap convergence tunnel positions can be judged by analyzing whether the tunnel structure is stable or not. Is the form correct (Akpan 1992) (Akpan et al. 2014). Therefore, finding the deformation law of its displacement will be a new breakthrough. The amount of monitoring data in the tunnel is determined by the number of monitoring sections, the layout of the measurement line, and the monitoring frequency. This is the function and significance of tunnel construction monitoring and measurement. According to engineering experience, this amount of data is often huge, and manual calculation is almost impossible (Allen 1965). Even the simplest data processing work requires a huge amount of storage. Therefore, the research on automated monitoring systems should be accelerated. Under the conditions of limited economy and time, before tunnel construction, the mechanical parameters of the tunnel-surrounding rock are determined mainly through limited drilling (Avbovbo 1978). Although it is somewhat difficult, the construction parameters of tunnel engineering are also determined accordingly. The calculation results may cause the actual deformation of the surrounding rock to be quite different from the predicted deformation, and accidents may be caused according to the original construction plan (Benkhelil et al. 1975). People should monitor and measure the tunnel engineering, calculate the mechanical parameters of the surrounding rock of the tunnel, and analyze the measured displacement changes to ensure long-term stable construction and support (Burke and Dewey 1974).

Research Design

Mechanical model of the tunnel-surrounding rock

Construction of the tunnel

Surrounding rock stability runs through the tunnel construction process, so the core of tunnel construction mechanics research is surrounding rock stability (Burke and Whiteman 1972) (Burke and Whiteman 1973). The initial stress field of the rock mass is composed of two force systems, as shown in formula (1):

$$\sigma = \sigma_y + \sigma_z$$

At the buried depth H, suppose there is a surrounding rock unit. At this time, the unit is in equilibrium under the action of three-dimensional stress, as shown in Fig. 1, and its initial stress is shown in Eq. (2):

$$\begin{align*}
\sigma_z &= \gamma H \\
\sigma_x &= \sigma_y = K_0 \sigma_z = K_0 \gamma H
\end{align*}$$

Secondary stress state

After the tunnel is excavated, the surrounding rock stress is redistributed, and even a small blasting may cause changes in geological conditions. The elastic secondary stress state of the surrounding rock after the tunnel excavation can be approximately expressed as Eq. (3):

![Fig. 1 Three-dimensional stress action diagram of surrounding rock unit](image)

![Fig. 2 Schematic diagram of the tunnel](image)

Table 1 Transverse section spacing table

| Excavation width and tunnel depth | Longitudinal measuring point distance(m) |
|-----------------------------------|----------------------------------------|
| 2B>H0>2.5B                       | 20–50                                  |
| B<H0≤2B                          | 10–20                                  |
| H0≤B                             | 5–10                                   |
\[
\begin{align*}
\sigma_r &= \frac{\sigma_y}{2} [(1-\alpha^2)(1 + K_0) + (1-4\alpha^2 + 3\alpha^4)(1-K_0)\cos2\theta] \\
\sigma_\theta &= \frac{\sigma_y}{2} [(1-\alpha^2)(1 + K_0) + (1 + 3\alpha^4)(1-K_0)\cos2\theta] \\
\tau_{r\theta} &= \frac{\sigma_y}{2} [(1-2\alpha^2 + 3\alpha^4)(1-K_0)\sin2\theta]
\end{align*}
\]

Among the abovementioned various stresses, the compressive stress is positive and the tensile stress is negative, as shown in Fig. 2.

(1) When \(Y = \alpha\), that is, when \(\alpha = 1\), the formula 3 variant (4):

\[
\begin{align*}
\sigma_r &= 0 \\
\sigma_\theta &= \sigma_y[(1-2\cos2\theta) + K_0(1 + 2\cos2\theta)] \\
\tau_{r\theta} &= 0
\end{align*}
\]

Substituting different \(K_0\) values (side pressure coefficient) into formula 4 can be obtained:

(1) When \(K_0 = 0\), formula 3 can be written as formula 5:

\[
\begin{align*}
\sigma_r &= \frac{\sigma_y}{2} [(1-\alpha^2) + (1-4\alpha^2 + 3\alpha^4)\cos2\theta] \\
\sigma_\theta &= \frac{\sigma_y}{2} [(1-\alpha^2) - (1 + 3\alpha^4)\cos2\theta]
\end{align*}
\]

(2) When \(K_0 = 1\), formula 3 can be written as formula 6:

\[
\begin{align*}
\alpha_r &= \alpha_y(1-\alpha^2) \\
\alpha_\theta &= \alpha_y(1+\alpha^2)
\end{align*}
\]

Arrangement of displacement monitoring and measuring points in the cave

The tunnel displacement monitoring points mainly include: vault settlement measurement points, foot settlement measurement points, and gap convergence measurement points. The measurement section spacing is shown in Table 2 below:

The measurement point of the vault subsidence should be set near the arch axis, and the measurement point of the head-space convergence and the arch foot measurement point should be symmetrically arranged on both sides of the tunnel axis (Burke et al. 1971). In the shallow-buried offset section of the tunnel or in the large-span tunnel, the observation points should be

| Table 3 | Survey line layout |
|---------|-------------------|
| Lot method | Usually A horizontal line Special |
| Full-face method | – |
| Step method | One for each step Add two oblique lines on the usual basis |
be appropriately encrypted, and an oblique baseline should be set, as shown in Fig. 4. The arrangement of specific observation points should be determined on site according to the construction method and surrounding rock conditions, refer to Table 3 below.

The embedment method of the observation points for the settlement of the vault and arch toe and the change of the gap is shown in Fig. 5 below.

**Comparison and selection of WebGIS and system development platform**

**WebGIS**

Compared with traditional geographic information, WebGIS has the following characteristics:

1. Users can access across geographic locations and use the advantages of the Internet to greatly enhance the data management of traditional geographic information, making it easier to implement distributed multi-information data sources and effective unified management of data (Cratchley and Jones 1965).

2. Different data types that can be shared remotely, with strong platform independence.

3. To effectively reduce system costs, traditional GIS users must install expensive dedicated GIS software, but the geographic information functions used by users are very limited, causing serious waste of funds and increasing the cost of using geographic information. However, WebGIS systems are far more convenient and the cost is significantly reduced. In addition, because the client browser is simple to use, the system maintenance cost is much lower than that of a professional GIS system.

4. Simple operation, geographic information system should be widely used, not only to make it serve professionals, but also to be popularized. Therefore, it is necessary to reduce the requirements for system operation. A universal web browser can effectively solve this problem and is the best choice to improve the simplicity of GIS operation (Ehinola et al. 2008).

**Comparison and selection of development platforms**

According to the functional requirements of the system, it is very important to select the appropriate development platform and technology.
The development of an efficient WebGIS system largely depends on the choice of the development platform. Currently, the more popular WebGIS platforms include HyperGraph-, MapINFO-, and ESRI-related products. The main functional characteristics are shown in Table 4:

It can be seen from Table 4 above that the cache mapping service can fundamentally improve the performance of the mapping response.

### Design of automatic monitoring system for tunnel-surrounding rock measurement

#### The overall structure of the tunnel construction safety monitoring system

The WebGIS-based tunnel construction safety monitoring system uses WebGIS to monitor information, network...
applications, and databases and other modern information technology methods to closely integrate the relevant knowledge of the tunnel monitoring project to realize a monitoring information management platform. The platform can help monitoring personnel to cross geographical restrictions, conveniently and effectively communicate and share monitoring data, railway tunnel construction monitoring information management. The structure of the monitoring information management system adopts a hierarchical structure, as shown in Fig. 6.

**Functional design of the monitoring system**

In the design of the functional modules of the system, the work nature of the tunnel construction safety monitoring is used, the tunnel monitoring data is the main body, combined with the monitoring data of the surrounding buildings, for monitoring point management, the data is organized, and the corresponding computer digital management mode is realized. The tunnel construction safety monitoring system is divided into six sub-function modules: monitoring data management, GIS basic map operation, monitoring data curve generation, file management and user management, monitoring data prediction, and prediction analysis (Ekpo et al. 2012) (Ekpo et al. 2013). Each sub-function module completes its own function separately, and has a certain connection with each other. In principle, it is a loose and low-coupling relationship at the data level. The functional structure of the system is shown in Fig. 7.

### Table 5: Model characteristic parameter table

| Parameter                  | Rock mass | Invert filling | Spray mixing | Anchor rod | Second liner |
|----------------------------|-----------|----------------|--------------|------------|--------------|
| Elastic modulus E (GPa)    | 2.0~6.0   | 2.8            | 2.8          | 21         | 3.1          |
| Poisson’s ratio            | 0.2       | 0.2            | 0.2          | 0.3        | 0.2          |
| Friction angle°            | 40        | –              | –            | –          | –            |
| Cohesion Mpa               | 250       | –              | –            | –          | –            |
| Severe tonf/m²             | 25        | 23             | 23           | 78.5       | 23           |
| Side pressure coefficient  | 0.5~1.0   | –              | –            | –          | –            |
| Thickness (diameter) mm    | –         | 23             | 23           | 25         | 40           |
Research results

Establishment of the tunnel model

This paper uses the MidasGTS software to establish a three-dimensional model of the tunnel construction project, and simulates the top surface of the model as a plane, regardless of the specific topography and topography of the ground, to simulate the construction of the DK950 + 960 ~ DK951 + 020 section, the strata, and the roadway support. The characteristic parameters of protective materials are shown in Table 5.

In the process of 3D tunnel modeling, the 3D model of the tunnel should be established according to the relevant data in the model defined in Table 5 above. Generally, the denser the mesh of the tunnel model is, the more accurate the calculation result will be. However, this will also extend the calculation time and affect efficiency. Rough division will affect the accuracy of the calculation. When the model is divided, the accuracy is relatively high due to the better rock mass conditions. The overall grid map of the model and the local grid division of the tunnel are shown in Figs. 8 and 9.

Figure 10 below is the vertical deformation displacement diagram of the model.

Calculation of back analysis of tunnel-surrounding rock displacement

According to the above description, we determine the elastic modulus E and related parameters. Here, the elastic modulus E can be calculated. At the same time, the calculated C and D are used as the new elastic modulus and substituted into the model.

According to the actual measurement results, the final settlement of the section vault of the DK950 + 980 tunnel is: D(Z) = 19.50 mm, as shown in Fig. 11; the change of the model is G(x) = G(4.472,0.5) = 21.20 mm, F(x) = [21.20–19.50] = 1.70 mm, the amount of change of the model can be obtained by adding result markers at the apex of the arch to get G(x) (Fig. 12).

According to the above analysis and comparison, the segmentation area needs to be re-divided accordingly. As shown in Fig. 13, substitute E = 5.056 into the tunnel model.

When E = 5.056, the model diagram is shown in Fig. 14. When E = 5.416, the model diagram is shown in Fig. 15. When E = 4.833 and K0 = 0.5, the model diagram shown in Fig. 16 can be obtained. According to the location of the tunnel construction site, the level change at a distance of 6 m from the vault is used as the headroom change of the model.

When E = 5.056 and K0 = 0.5, as shown in Fig. 17, the result still does not meet the accuracy requirements.

Comparative analysis of back analysis results of tunnel-surrounding rock displacement

The counter analysis result statistics are shown in Table 6 below.

According to the model results, the comparison of the measured tunnel results is shown in Table 7 below.

It can be seen from the above Table 7 and the curve that the agreement is good. The back analysis results of DK950 + 960, DK951 + 000, DK951 + 020, and other cross-sections can also be obtained by the same method. The same method will not be repeated here. The results are now listed in Table 8.

Discussion and analysis

Function design of the automatic monitoring system for tunnel-surrounding rock measurement

Data entry and storage

Through this function, the user can input the initial value of the section, add and calculate the daily data, so as to realize the management of the collected tunnel field monitoring data. The input information includes: road mileage, measurement point,
collection time, date, three collected values and facial mileage. When entering the initial value, you also need to enter the tunnel name. For the damaged rearrangement point, you need to enter the rearrangement time and the corrected value after the rearrangement. We designed a batch data import function in the system design, mainly to understand the problem of huge amount of data and the difficulty to store. The operation is also very simple; as long as you select the bulk import button on the main page, the corresponding data import interface will pop up (Ekwok et al. 2019). At this point, click “Browse” in the window, select the Excel file that contains the data to be imported, and click the “Import Table Type” button, and the entire import function is completed.

Data query function

In the first step, you can enter the name of the tunnel and the start and end time. In the second step, the distance and points can be easily searched for historical data. Enter the specific point in a period of time, and the corresponding cumulative change curve over time change and its logarithmic model (Ekwok et al. 2020). To query historical data by tunnel, you need to enter the tunnel name and query date, and you can query all the data of the tunnel to be tested on the same date. The two query modes, query by point and query by tunnel, perform simple and effective queries on historical data from the vertical and horizontal directions, and can basically meet the requirements of users for data query (Ekwok et al. 2020).

Data analysis, early warning, and forecasting functions

The management system can not only automatically calculate and store monitoring data, but also analyze and process the data to avoid calculation errors. In addition, the system can automatically complete the early warning and forecast functions of the monitoring data. This paper studies and establishes the
Fig. 12 When $E = 3.528$, the settlement model of the section

Fig. 13 The model diagram of the section settlement when $E = 5.056$

Fig. 14 Sectional settlement model diagram when $E = 5.416$
Fig. 15  $E = 4.833$ Sectional settlement model diagram

Fig. 16  Cross-section headroom convergence model diagram

Fig. 17  Cross-section headroom convergence model diagram when $E = 5.506$. 

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monitoring data displacement control benchmark, the monitoring data safety management level, and the three-level risk early warning management level. By setting the threshold monitoring data, the system can generate a report and judge the value of threshold setting according to law (Ekwueme et al. 1995). The part where the displacement change rate is less than the threshold point is normal. Once the deformation is greater than the threshold value, the page will not only display red, but also a dialog box will pop up with “Warning” to remind the operator to carry out the displacement operation (Essien et al. 2005).

Report generation function

(1) Daily report generation: As the name suggests, the daily report is to analyze and process the results measured yesterday, and then hand it over to the construction unit to guide on-site construction.

(2) The generation of weekly report: Similar to the daily report, it analyzes and processes the results measured in the previous week every week, and then submits it to the construction unit to guide on-site construction. In addition to the data table, the weekly report also includes a change curve report and a trend line of cumulative changes. Mainly by selecting the start and end date and the name of the tunnel-batch generated data, then export the data to a folder and name the data post-processing software in the same folder, open the post-processing software, and select “Batch import and output PDF” to carry out (Esu et al. 2009).

System environment design

System operating environment

The advantage of this system is that it does not require any configuration from the user, because in order to facilitate the user’s use, the selected client is configured in advance, and the relevant plug-ins are also installed in advance. Therefore, the user can realize the corresponding function only through the browser. Compared with other complicated systems that require various plug-ins to complete the use, it is not only convenient and fast, but also greatly reduces the user’s traffic consumption:

(1) Client operating environment

- MicrosoftInternetExplorer6.0
- MicrosoftWindows98/NT/2000/XP

(2) Server-side operating environment

- MicrosoftWindows2003Server
- MicrosoftIIS6.0
- SQLServer2000
- ArcGISServer9.3

System development environment

As shown in Table 9, the map data can be processed by dragging and dropping layers and editing. Create a new MapService service and publish the map through simple operations. The specific development environment is shown in Table 9.

Surrounding rock deformation control principles and technical system

Principles of surrounding rock deformation control

Surrounding rock deformation is controlled within the allowable range. The general principle of tunnel deformation

Table 6 Statistical table of cross-section back analysis results

| Parameter                  | Range | Displacement (mm) | Back analysis | Positive analysis (mm) | Absolute error (mm) | Relative error (%) |
|---------------------------|-------|-------------------|---------------|------------------------|---------------------|-------------------|
| Elastic modulus E (a)     | 2GPa  | 19.50             | 4.833GPa      | 19.60                  | 0.10                | 0.51              |
| Elastic modulus E (b)     | 6GPa  | 19.50             | 5.056GPa      | 18.74                  | 0.76                | 3.90              |
| Side pressure coefficient K0 (a) | 0.5   | 18.48             | 0.927         | 17.70                  | 0.78                | 4.22              |
| Side pressure coefficient K0 (b) | 1     | 18.48             | 0.972         | 19.29                  | 0.81                | 4.38              |

Table 7 Displacement and deformation comparison table of section

| Construction stage Company | Spray mixing | Excavation | Filling | Perform |
|----------------------------|--------------|------------|---------|---------|
|                            | Model (mm)   | Measured (mm) | Model (mm) | Measured (mm) | Model (mm) | Measured (mm) | Model (mm) | Measured (mm) |
| Vault settlement           | 13.14        | 12.12      | 18.10   | 17.27   | 18.56   | 18.36   | 19.22   | 19.50   |
| Horizontal convergence displacement | 15.34     | 10.61     | 18.22   | 15.91   | 18.51   | 16.70   | 18.6    | 18.48    |
control is that after the support is set up, the total deformation value must be controlled within the allowable shape value range (Hinze 2003).

Generally speaking, in the process of tunnel excavation, for the surrounding rock with better stability, the surrounding rock has a certain self-stabilization time after the tunnel excavation, so as to ensure that the initial support has sufficient running time. In this kind of surrounding rock, the initial support should bear all the loads released after the tunnel is excavated. The stability is poor. After the tunnel is excavated, the surrounding rock stability is very short. Early application of bolt support may cause the surrounding rock deformation to exceed the allowable range. In this type of surrounding rock, advanced supporting measures should be adopted to reduce problems that occur after excavation, such as the ability to release the preload, initially support the release of the load reduction after the excavation of the advance support, and the advance support and initial support of the surrounding rock after the excavation can release all the loads of the surrounding rock. For the special surrounding rock with poor stability, the secondary lining gun should be designed according to the structure with mechanical functions.

Therefore, under general principles, we control the deformation of different types of surrounding rocks as shown in Table 10.

### The tunnel-surrounding rock deformation control technology system

#### Overview of the development of the tunnel-surrounding rock deformation control technology

In recent years, the successful construction of a large number of tunnel projects based on scientific and technological research results has significantly improved the technical level of soft rock deformation control in deep-buried tunnels, which has greatly promoted the progress of tunnel construction projects.

After more than 30 years of historical precipitation, China’s tunnel engineering is developing rapidly, and it is also leading the development of regional tunnel and railway tunnel technology. Although some aspects of China’s railway tunnel technology have reached the international advanced level, there are still some conceptual and technical problems. Due to the lack of traditional understanding of the role of initial support, the technical measures of many projects are difficult to reliably control the stability of the surrounding rock, the quality of some procedures is difficult to guarantee, and the level of construction equipment needs to be improved urgently. Facing the large deformation of soft rock, most tunnel construction procedures are mainly manual operation, and the management level of tunnel construction site is not high. There is a lack of coordination and unity of science, safety, efficiency, and economy in construction. There is not a strong awareness of the number of roadways to optimize, and most of them work on parallel interfaces, resulting in a large distance of support closure. The construction period is unreasonable, and the construction safety and construction quality cannot be effectively guaranteed under the condition of large deformation of the weak surrounding rock.

#### Construction process of surrounding rock deformation control

Previous studies have shown that the deformation of the surrounding rock of a large section often starts from a small part. In particular, large deformation disasters usually start from a small point, expand to a part, and then become several parts. It

| Table 8: The back analysis results of each section |
|-----------------------------------------------|
| Section mileage | Elastic modulus E | Side pressure coefficient | Tolerance scope |
| DK950+960       | 3.968~4.742       | 0.834~0.938              | <1.0           |
| DK950+980       | 4.833~5.056       | 0.927~0.972              | <1.0           |
| DK951+000       | 4.153~4.982       | 0.798~0.913              | <1.0           |
| DK951+020       | 4.782~5.273       | 0.892~0.957              | <1.0           |

#### Table 9: System development environment

| Development environment | .Netstudio2008 |
|-------------------------|---------------|
| Operating system platform| Windows XP   |
| Database server         | SQLServer2000+ADO.NET |
| Web server              | IIS6.0        |
| GIS development components | ArcGISAPI for JavaScript |
| Map Maker               | ArcMAP        |
can be said that it has obvious space-time effects. Therefore, the basic idea of successfully controlling the deformation of the surrounding rock is to choose a suitable construction method to reduce the loosening of the surrounding rock of the tunnel as much as possible, so as to stifle the occurrence of disasters in the cradle and give full play to the bearing capacity of the surrounding rock of the tunnel. According to the study of modern rock mechanics, rock mass excavation has the characteristics of "memory," the next stage of rock mass excavation has the "memory" of the previous stage of excavation behavior, and there are generally five excavation methods for weak and broken surrounding rocks. As shown in Table 11, the five construction methods are analyzed.

### Conclusion

In this paper, combined with the monitoring project of the green railway tunnel, the tunnel construction monitoring is studied. The main research contents and conclusions are as follows: establish a total station measurement free adjustment calculation model, and then collect, calculate, and analyze the data of the tunnel-surrounding rock deformation, and use the calculation The accuracy obtained is used to determine the applicable scope of the standing position of the total station. After determining the position of the total station, the monitoring of the tunnel within the range of 30–90 m can be adjusted appropriately, so that when the instrument is blocked, the accuracy of monitoring the settlement of the tunnel vault can be ensured. At the same time, it can ensure convergence to obtain good measurement accuracy, and the flexibility of monitoring operations can also be improved. This paper studies and establishes the monitoring data displacement control benchmark, the monitoring data safety management level, and the three-level risk early warning management level. By setting the threshold monitoring data, the system can generate reports and make threshold setting value judgments in accordance with the law. In addition, the deformation law of the surrounding rock of the tunnel is analyzed, and the application effect of the total station and its supporting system in the

### Table 10  Deformation control principles for different types of the tunnel-surrounding rock

| Deformation control principle | Type of surrounding rock | Remarks |
|------------------------------|--------------------------|---------|
| Principle one                | All loads released after excavation are borne by the initial support | Relatively good stability | When the tunnel is excavated, the surrounding rock will have a certain amount of self-stabilization time, and there will be enough construction time for the initial support |
| Principle two                | All loads released after excavation are borne by the advance support and the initial support | Poor stability | The self-stabilization time of the surrounding rock is very short after the tunnel is excavated, and the initial support lacks construction time, and the surrounding rock may deform beyond its allowable range |
| Principle three              | When the deformation does not converge for a long time, use the secondary lining to bear the load of the non-convergent part | Long-term deformation does not converge | The surrounding rock has obvious post-excitation deformation, and it takes a long time to deform to converge. At this time, the secondary lining gun should be designed as a structure with mechanical functions |

### Table 11  Performance comparison of construction methods suitable for super-large section high-speed rail tracks

| Construction method | Double sidewall pilot pit | Cross next door | Three steps and seven steps excavation | Three pilot holes | Next door |
|---------------------|---------------------------|-----------------|----------------------------------------|------------------|----------|
| Performance         | Safety                    | Safer           | Not safe enough                        | Safety           | Safer    |
| Safety              | Very high                 | High            | Low                                    | Very high        | Higher   |
| Construction difficulty | Many                     | Many            | Simple                                | Many             | More     |
| Process             | Great                     | Great           | General                               | Great            | Better   |
| Face stability      | Harder                    | General         | Easy                                  | Harder           | General  |
| Cooperating auxiliary method | Small                 | Small           | Large and medium                      | Small            | Medium and small |
| Mechanical adaptability | Slow                    | Slow            | Fast and short                        | Slow             | Slower   |
| Construction period | High                      | High            | Low                                   | High             | Higher   |
| Cost                | Difficult                 | Difficult       | Easy                                  | Difficult        | Harder   |
| Process conversion  | General                   | General         | Strong                                | General          | Stronger |
| Geological adaptability | Great                   | Better          | Poor                                  | Great            | Better   |
| Surrounding rock deformation control | General           | Preference     | Well                                  | General          | Better   |
monitoring of the surrounding rock of the tunnel is discussed. If it is applied to practice and the relevant monitoring information is fed back to the construction team, it will definitely benefit a lot. This paper firstly analyzes the monitoring data by the gray theory, and predicts the short-term deformation of the tunnel-surrounding rock by establishing a three-dimensional geometric model of the gray system. Secondly, the regression analysis is combined with it, and a combined forecasting method is proposed. The total station mentioned here is used to monitor the collapse of the Huashantun tunnel field, and combines the prediction method of the combination prediction method, the change of the surrounding rock, the stability time of the surrounding rock, and the final deformation of the tunnel. It provides a theoretical basis for the next to optimize the construction plan and guide the construction to solve the tunnel collapse problem. Combined with the measured data of the DK950 + 980 cross-section of a tunnel on a shady slope, the specific steps of the displacement back analysis are introduced. Before the back analysis, the media model of the rock mass around the tunnel must be determined first, and on this basis, the specific parameters to be back analyzed must be determined. Then, according to the medium model and the corresponding parameters to determine the tunnel construction process, the reasonable parameter selection range and the correct tunnel geometry model make the established meshing more reasonable. Generally, the denser the mesh of the tunnel model is, the more accurate the calculation result will be. However, this will also extend the calculation time and affect efficiency. Rough division will affect the accuracy of the calculation. Therefore, the use of mathematical methods to select the parameters reasonably needs to be solved. You can try to reduce the error caused by the deformation of the tunnel-surrounding rock by introducing the finite element model and the range of parameters.

Acknowledgments This work is funded by the National Natural Science Foundation of Henan Province (212300410327).

Declarations

Conflict of interest The authors declare that they have no competing interests.

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