eJSE International

Electronic Journal of Structural Engineering 22 (1) 2022

Evaluation Method of Highway Quality and Safety Based on Finite Element Analysis

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ABSTRACT: In order to accurately evaluate the quality of highway tunnel engineering, the finite element analysis is used to evaluate the quality of highway tunnel secondary lining structure, and the slotting method and finite element analysis are used to analyze the working stress of tunnel secondary lining structure and the back analysis of the load on the secondary lining structure. The test results show that the error rate of the working stress of the secondary lining structure deduced by combining the slotting method and finite element analysis is 2.22%, the average error rate of the vertical uniformly distributed load analysis of the two lane and three lane highway tunnels is 7.09%, and the average error rate of the horizontal lateral pressure coefficient analysis is 16.37%. The numerical errors are within the acceptable accuracy range of the actual highway tunnel engineering. Using finite element analysis to analyze the quality and safety of highway tunnel can accurately evaluate the quality and safety of the secondary lining structure of tunnel engineering, and provide effective data reference for the actual quality evaluation and defect reinforcement of tunnel engineering.

Keywords: Finite element analysis, Slotting method, Highway tunnel, Secondary lining structure, Safety evaluation

1 INTRODUCTION

In recent years, the design and construction technology of tunnel engineering have developed continuously, but the quality level of tunnel engineering is greatly affected by the surrounding rock environmental conditions, and the characteristics of underground construction of tunnel engineering also increase the construction difficulty of tunnel construction, resulting in construction quality problems such as insufficient thickness of secondary lining and cavity behind tunnel construction engineering. The quality of tunnel construction is directly related to the driving safety of expressway. The quality problems of tunnel engineering may induce collapse accidents in the subsequent construction process, and may even affect the operation safety and durability of tunnel . In recent years, the construction standards and specifications of tunnel engineering have been continuously improved, and the quality supervision of highway tunnel construction by relevant departments has been increasing. However, there are differences between the load of tunnel structure and the ideal state of parameters in actual engineering. For a long time, there has been a lack of safety evaluation system to scientifically evaluate the actual quality level of highway tunnel secondary lining structure.

Finite element analysis is one of the important means of performance analysis and safety evaluation. Many researchers use finite element analysis method in safety and risk assessment. Aiming at the landslide problem along the highway, Sarkar s and other scholars proposed a quantitative assessment scheme of landslide disaster risk based on finite element analysis to assess the stability of cutting slope along the highway, quantify the potential and existing landslide risk level of the highway, and realize highway landslide risk management. Zhang T and his team put forward a safety evaluation scheme for reinforced concrete structures under freeze-thaw cycle and acid rain corrosion environment. Using finite element analysis to simulate the axial compression performance of reinforced concrete columns under the combined action of freeze-thaw cycle and acid rain, they predicted and analyzed the residual bearing capacity of reinforced concrete short columns under axial compression, and put forward the prediction formula of residual bearing capacity. The experimental results show that the research prediction accuracy is high, The predicted value is in good agreement with the actual situation. Based on the finite element analysis, Chen j et al. Evaluated the overall safety of the dam under the action of earthquake, established the seismic damage index system of high arch dam, analyzed the seismic response in combination with the incremental dynamic analysis method, and detected and evaluated the damage of the dam after the earthquake. From the research results of finite element analysis, it can be seen that finite element analysis has obvious advantages in safety evaluation. Therefore, based on finite element analysis and starting from the actual stress situation of the secondary lining structure, the research evaluates and analyzes the quality and safety of highway tunnel, hoping to put forward a more effective evaluation method for the quality and safety of the secondary lining structure of highway tunnel.

2 QUALITY EVALUATION OF SECONDARY LINING STRUCTURE OF HIGHWAY TUNNEL BASED ON FINITE ELEMENT ANALYSIS

2.1 *Actual stress analysis of secondary lining structure based on slotting method*

Highway tunnel is an important infrastructure of expressway. The quality of highway tunnel is directly related to the safety and stability of Expressway driving (Mahmud et al. 2020). New austrian tunnelling method (NATM) is a common method for highway tunnel construction at present. In tunnel engineering construction, combined with rock mass mechanics theory, bolt and shotcrete are used as the main support means of the tunnel (Chen & Liu 2019, Hinds et al. 2021). The insufficient thickness of secondary lining is one of the common problems of tunnels constructed by NATM. According to the industry evaluation standards, the defective sections need to be reworked. However, in the actual highway tunnel engineering, the actual bearing pressure of the secondary lining structure is small, which is protected by the advance support and anchor bolt, and the surrounding rock of the tunnel may not be loose (Rezapour et al. 2019, Shokrgozar et al. 2021). Therefore, simply evaluating the construction quality and safety of the highway based on the thickness of the secondary lining can not reflect the actual quality level of the highway. The stress release method is used to test the concrete stress of the secondary lining structure of the highway tunnel, combined with the slotting method to evaluate the actual stress condition of the secondary lining structure, and calculate the load it bears, Compare the back calculated load with the actual bearing capacity of the secondary lining structure, so as to evaluate the safety quality of the secondary lining structure of the highway tunnel, and build the quality and safety evaluation system of the highway tunnel based on the actual stress analysis. The safety evaluation process is shown in Figure 1.

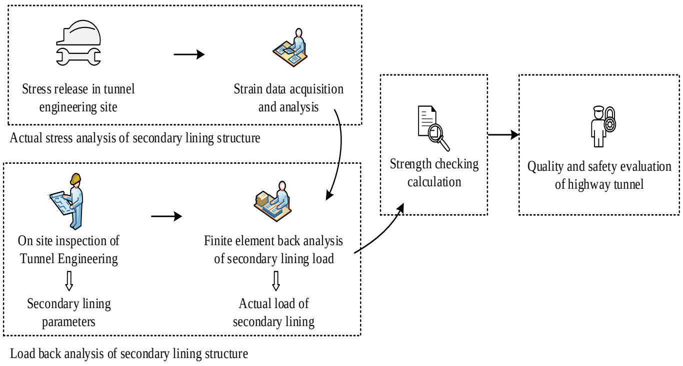


Figure 1. Quality and safety evaluation system of highway tunnel based on actual stress analysis

Starting from the actual stress, the quality and safety of the highway are evaluated. The highway tunnel is analyzed by using the ANSYS finite element analysis software, the physical situation of the highway tunnel is simulated by using the mathematical approximation method, the three-dimensional finite element model of the highway tunnel is established, and the actual working internal force of the secondary lining structure of the highway tunnel is analyzed and studied. The geological conditions of the environment where the highway tunnel is located and other factors have an impact on the stress of the tunnel structure. Therefore, starting from class IV surrounding rock and class V surrounding rock, the stress of the secondary lining structure of the highway tunnel under the standard two lane and standard three lane is analyzed. Referring to the code for design of highway tunnels (JTG 3370.1-2018), the design load bearing ratio of the tunnel secondary lining structure is 60%. The plane beam element is used to simulate the secondary lining structure, and the curved spring element is used to simulate the elastic resistance of the stratum to the secondary lining structure. The parameters of the finite element model are shown in Table 1.

Table 1. Finite element model parameters

PARAMETER		STANDARD TWO LANE	STANDARD THREE LANE
EXCAVATION HEIGHT (M)		10.2	10.3
EXCAVATION WIDTH (M)		11.4	15.6
CONCRETE STRENGTH		C25	C25
ELASTIC MODULUS (GPA)		29.5	29.5
POISSON'S RATIO		0.2	0.2
CLASS IV SURROUND-	Secondary lining thickness (cm)	40	50

ING ROCK	Resistance factor (MPa/m)	200-500	200-500
CLASS V SURROUNDING ROCK	Secondary lining thickness (cm)	45	60
	Resistance factor (MPa/m)	100-200	100-200

The core of the working stress problem of concrete members lies in the complete stress release depth. The slotting method is used to analyze the stress release, and the actual stress of the secondary lining structure of highway tunnel is studied. By slotting the concrete members under load, the slotting method restores the elasticity of the concrete members due to the release of the surrounding constraints, resulting in stress redistribution (Shao et al. 2021, Shen et al. 2021). When the slotting depth reaches the depth condition of complete stress release, the stress change in the stress release process is measured and inversed to realize the calculation and analysis of the working stress in the measurement area of concrete components (El-Sayed et al. 2021, Gk et al. 2021). The schematic diagram of drilling operation of slotting method is shown in Figure 2. An annular groove is drilled on the measuring area of concrete components, and a resistance strain gauge is placed in it to measure the strain. Figure (a) shows the side view of the concrete component and figure (b) shows the top view of the excavated annular groove. A resistance strain gauge is placed in the center of the bottom of the annular groove to measure the strain of the component.

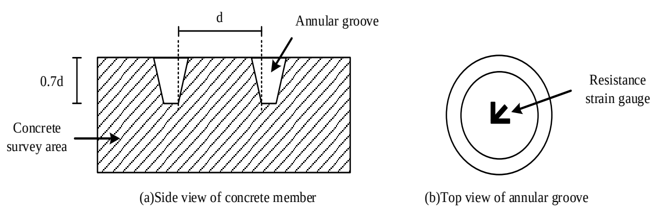


Figure 2. Schematic diagram of drilling operation of slotting method

For concrete members under unidirectional working stress, slotted drilling shall be carried out along the action direction of load, and resistance strain gauges shall be pasted (Li et al. 2020). The working stress calculation function of the measuring point is expressed as follows:

$$\sigma = -E\varepsilon \tag{1}$$

In formula (1), σ represents the working stress of the measuring point, ε represents the strain release after the working stress is completely released, and E represents the elastic modulus of the concrete member. For concrete members under plane working stress, slotted drilling is carried out in the survey area, and the stress change is measured by pasting strain Flowers (He et al. 2020). Suppose that the stress variables after complete stress release are ε_1, ε_2 and ε_3, and the maximum and minimum principal stresses at the measuring point are σ_1 and σ_2. Measure the initial stress at the measuring point. After stress release, the strain $\varepsilon(\alpha)$ at an angle α with the direction of principal stress σ_1 is expressed as follows:

$$\varepsilon(\alpha) = K(\alpha)\sigma_1 + K\left(90^\circ - \alpha\right)\sigma_2 \tag{2}$$

In formula (2), $K(\alpha)$ is a parameter variable that changes periodically with the included angle α, and the coefficient $K(\alpha)$ is expressed as follows:

$$K(\alpha) = A + B\cos 2\alpha \tag{3}$$

In formula (3), A and B are release coefficients. By introducing equation (3) into equation (2), the strain $\varepsilon(\alpha)$ can be expressed as follows:

$$\varepsilon(\alpha) = [A + B\cos 2\alpha]\sigma_1 + \left[A + B\cos\left(90^\circ - \alpha\right)\right]\sigma_2 \tag{4}$$

Assuming that 45 ° strain rosette is used for strain measurement and the angle of strain gauge is $\theta_1 = 0$, $\theta_2 = 45^\circ$ and $\theta_3 = 90^\circ$, the functions of strain ε_1, ε_2 and ε_3 are as follows:

$$\begin{cases} \varepsilon_1 = [A + B\cos 2\alpha]\sigma_1 + \left[A - B\cos\left(90^\circ - \alpha\right)\right]\sigma_2 \\ \varepsilon_2 = [A + B\sin 2\alpha]\sigma_1 + \left[A - B\sin\left(90^\circ - \alpha\right)\right]\sigma_2 \\ \varepsilon_3 = [A - B\cos 2\alpha]\sigma_1 + \left[A - B\sin\left(90^\circ - \alpha\right)\right]\sigma_2 \end{cases} \tag{5}$$

By solving equation (5), we can get:

$$\begin{cases} \sigma_1 = \dfrac{\varepsilon_1 + \varepsilon_3}{4A} - \dfrac{1}{4B}\sqrt{\left(\varepsilon_1 - \varepsilon_3\right)^2 + \left(2\varepsilon_2 - \varepsilon_1 - \varepsilon_3\right)^2} \\ \sigma_2 = \dfrac{\varepsilon_1 + \varepsilon_3}{4A} - \dfrac{1}{4B}\sqrt{\left(\varepsilon_1 - \varepsilon_3\right)^2 + \left(2\varepsilon_2 - \varepsilon_1 - \varepsilon_3\right)^2} \\ \tan 2\alpha = \dfrac{2\varepsilon_2 - \varepsilon_1 - \varepsilon_3}{\varepsilon_1 + \varepsilon_3} \end{cases} \tag{6}$$

When the working force of the measuring point is completely released, the release coefficients A and B are expressed as follows:

$$\begin{cases} A = \dfrac{\varepsilon_1 + \varepsilon_2}{2\sigma}E \\ B = \dfrac{\varepsilon_1 - \varepsilon_2}{2\sigma}E \end{cases} \tag{7}$$

2.2 *Load back analysis and safety evaluation of secondary lining structure*

In the actual highway tunnel engineering, it is difficult to calculate the load from the internal force of the tunnel secondary lining structure through a simple formula. The back analysis method is usually used for back calculation research. The initial parameters are calculated by using the measured internal force information or displacement information of the secondary lining structure on the construction site and combined with the inversion model system (Viet & Zaki 2021, Li et al. 2019). Based on the surface strain of the secondary lining of the highway tunnel, the load on the secondary lining structure is back analyzed. Combined with the actual stress analysis of the secondary lining structure, the quality and safety evaluation system of the highway tunnel based on the actual stress is constructed. The load of secondary lining structure of highway tunnel is greatly affected by surrounding rock grade, cavern shape, cavern span, tunnel buried depth and initial support. The classification of surrounding rock is directly related to the design and construction of highway tunnel engineering. There are differences in physical properties between different types of surrounding rock, and their rock hardness and self stability characteristics are different. It is necessary to adjust the support structure design scheme, excavation method and construction time according to the geological environmental conditions of the project area (Chehlafi et al. 2019). The tunnel shape and span of highway tunnel also have an impact on the load of secondary lining structure. Different tunnel shapes produce different plastic areas under in-situ stress. The tunnel shape of current highway tunnel is generally between horseshoe shape and longitudinal ellipse, showing a flat shape (Hinds et al. 2021, Shen et al. 2019). The stress of highway tunnel under this shape is uniform, but there is load relaxation in the surrounding rock mass, and the surrounding rock pressure borne by its supporting structure is greater. The cavern span directly affects the stability of highway tunnel structure. The cavern span is inversely related to the stability. The increase of cavern span will further aggravate the load relaxation of surrounding rock mass (Zheng et al. 2019).

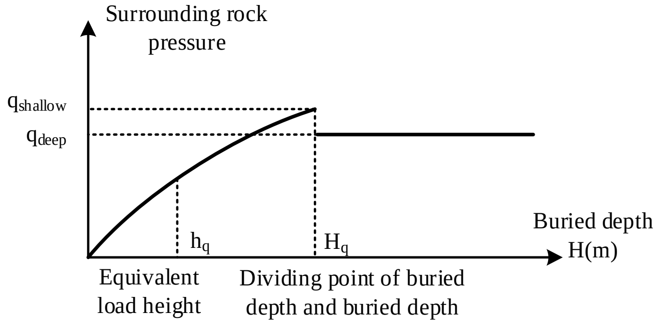


Figure 3. Relationship between buried depth of cavern and surrounding rock pressure

The relationship curve between the buried depth of the tunnel and the surrounding rock pressure is shown in Figure 3. When the buried depth of the tunnel is less than or equal to the equivalent load height, the surrounding rock pressure increases linearly with the increase of the buried depth of the tunnel. When the buried depth of the tunnel is greater than the equivalent load height and less than the boundary between deep and shallow burial, the surrounding rock pressure shows a parabolic growth trend. When the buried depth of the cavern is greater than the dividing point, it is in the deep buried state, and the surrounding rock pressure remains at a stable value. The highway tunnel construction under NATM adopts bolt shotcrete for initial support, especially in the shallow buried section of the tunnel with poor geology. Bolt shotcrete support can effectively reduce the formation pressure borne by the lining structure, and the sharing proportion of initial support will directly affect the load on the secondary lining structure of the tunnel [25]. Combined with the finite element model of the highway tunnel, the load on the secondary lining structure is back calculated and analyzed according to the surface strain of the secondary lining structure. The objective function of the back analysis of the elastic problem of the secondary lining structure is expressed as follows:

$$J(x)=\sum_{i=1}^{N}\left[f_i(x)-y_i\right]^2 \tag{8}$$

In equation (8), $(x)=(P,\lambda,E,\mu)$, where P represents the vertical uniformly distributed load, λ represents the horizontal lateral pressure coefficient, E represents the elastic modulus, μ represents the Poisson's ratio, $f_i(x)$ represents the measured and calculated value of the i parameter, including external load and highway tunnel parameters, y_i represents the measured actual value of the i parameter, and N represents the number of field measured parameters. The inverse analysis method is used to solve the objective function and find the appropriate parameter combination (x^*) to minimize the value of the objective function. P and λ

are unknown quantities to be solved, and the linear equation between the unknown quantities to be solved and the measured data is expressed as follows:

$$[K]\{x\}=\{y\} \tag{9}$$

In equation (9), $[K]$ represents the influence coefficient array of unknown quantity, $\{x\}$ represents the array of unknown quantity to be solved, and $\{y\}$ represents the array of known quantity. Let the number of unknown quantities to be obtained be M, and the error between the estimated best value x_j of the measured data and the measured value be ε_i. The formula of the measured actual value is as follows:

$$\begin{cases} y_i = \sum_{j=1}^{M} k_{ij} x_j + \varepsilon_i \\ i = 1, 2, \cdots, N \end{cases} \tag{10}$$

In equation (10), k_{ij} is the influence coefficient of unknown quantity to be solved. When $N > M$, that is, the quantity of measured data is greater than the quantity of unknown quantity to be calculated, the objective function of inversion analysis is expressed as follows:

$$J(\{x\}) = \sum_{i=1}^{N} \varepsilon_i^2 = \sum_{i=1}^{N} \left(\sum_{j=1}^{M} k_{ij} x_j - y_i \right)^2 \tag{11}$$

In order to achieve the goal of minimizing the sum of squares between the estimated optimal value and the measured value, the required conditions are expressed as follows:

$$\begin{cases} \dfrac{\partial J(\{x\})}{\partial x_j} = 0 \\ j = 1, 2, \cdots, M \end{cases} \tag{12}$$

In equation (12), ∂ means partial derivative. Substitute the condition formula, and the objective function is expressed as follows:

$$\begin{cases} \sum_{i=1}^{N} \left(k_{ij} \sum_{l=1}^{M} k_{il} x_l \right) - \sum_{i=1}^{N} k_{ij} y_i = 0 \\ j = 1, 2, \cdots, M \end{cases} \tag{13}$$

In equation (13), x_l represents the l unknown quantity. The least square method is used to optimize the objective function equation. The linear algebraic equations of P and λ are expressed as follows:

$$\{x\} = \left([K]^T [K] \right)^{-1} [K]^T \{y\} \tag{14}$$

In equation (14), T represents transposed rows and columns. After the load back analysis of the secondary lining structure, it is necessary to check the strength of the secondary lining structure, determine the ultimate bearing capacity N_J of the secondary lining structure through the ultimate strength with reference to the highway tunnel design code, and obtain the safety factor K in combination with the actual axial force N_S under the working state of the secondary lining structure. When the axial force eccentricity is $e_0 = 0.20h$, the compressive strength formula of highway tunnel lining structure section is as follows:

$$K = \frac{N_J}{N_S} = \frac{\varphi \alpha R_a b h}{N_S} \geq K_G \tag{15}$$

In equation (15), φ represents the longitudinal bending coefficient of the member, R_a represents the compressive ultimate strength of the masonry, b represents the width of the section, h represents the thickness of the section, and K_G represents the safety factor of the standard specification. When the axial force eccentricity is $e_0 > 0.20h$, the tensile strength formula of the eccentric compression member of the section is as follows:

$$K = \frac{N_J}{N_S} = \varphi \frac{1.75 R_l b h}{\frac{6e_0}{h} - 1} \Big/ N_S \geq K_G \tag{16}$$

In formula (16), R_l represents the ultimate tensile strength of concrete members.

3 TEST AND RESULT ANALYSIS

3.1 *Stress analysis test*

The slotting method is used to analyze the actual stress situation of the secondary lining structure, and the stress release depth of the component is experimentally studied. The dry cutting method is used to open an annular groove on the specimen to avoid the influence of concrete water absorption on the strain test result data. The influence of temperature conditions on the data is deducted during data collection, and the complete stress release law of the component is analyzed. During the slotting test, the test load is loaded in three levels, and the slotting cutting is carried out in an analysis step of 5 mm. The readings are taken about 20 minutes after the grooving is completed, and the stress change values under the corresponding states are recorded and counted. The strain values of the test piece under the three-level load are shown in Table 2.

Table 2. Strain value of specimen under level III load

LOAD VALUE (KN)	STRAIN VALUE OF MEASURING POINT	
	A1	A2
100	-17	-20
300	-67	-69
500	-130	-141

It can be seen from table 2 that three-level loading is used for test load loading, and the strain value of measuring point A1 under 500 kN load is -130 με, the strain value of A2 measuring point is -140 με, maintain 500 kN load for subsequent slotting. The slotted strain values at the two measuring points of the test piece are shown in Figure 4.

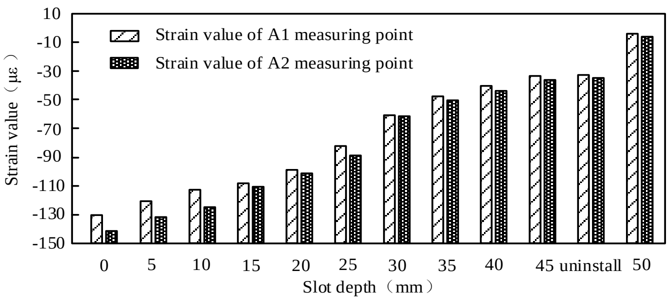


Figure 4. Grooving strain values at two measuring points of the specimen

It can be seen from Figure 4 that with the increase of the slotting depth, the stress value of the specimen increases and the stress is released gradually. When the slotting depth is 45 mm, the strain values of measuring point A1 and A2 gradually stabilize at -30 με On the left and right, the strain values of measuring point A1 and measuring point A2 are basically the same. It can be judged that 45 mm is the depth of concrete stress release. The stress release of members under finite element numerical analysis is shown in Figure 5.

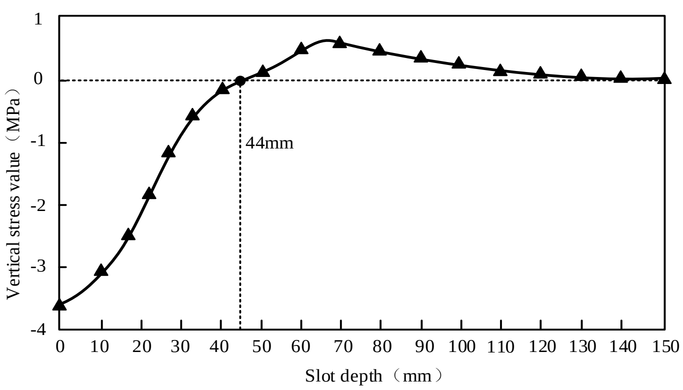


Figure 5. Stress release of components under finite element numerical analysis

It can be seen from Figure 5 that when the slotting depth gradually increases from 0 to 44 mm, the stress release speed of the component is faster and presents an approximate linear law. When the slotting depth is 44 mm, the component stress is completely released. With the continuous increase of the slotting depth, the stress value turns to positive value. The stress development law obtained from the analysis is basically consistent with the actual stress change law. The fully released slotting depth under the finite element numerical analysis is basically consistent with the slotting depth obtained from the test, with a difference of 1 mm and an error rate of 2.22%. Combined with the slotting method and finite element analysis, the actual stress of the secondary lining structure of highway tunnel is analyzed and studied. The error between the analyzed data and the actual data is small and the analysis accuracy is high.

3.2 *Safety parameter detection test*

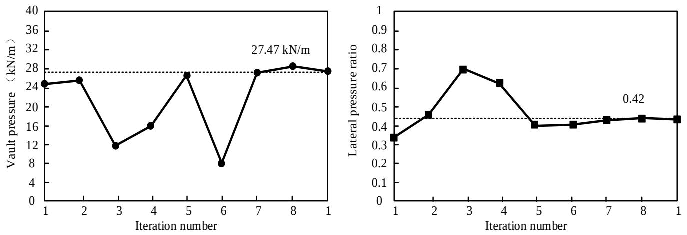
In order to verify the effectiveness and feasibility of the designed safety evaluation system, two tunnels are tested, and the tunnel parameters are analyzed by using the highway tunnel quality and safety evaluation system based on finite element analysis. Tunnel a crosses the mountain in a nearly north-south direction. It is a two tunnel two lane highway tunnel. The width of the tunnel is 10.25 m, the height of the tunnel is 5 m, the maximum buried depth of the tunnel is about 337 m, and the entrance portal and exit portal of the tunnel are end wall type. Tunnel B is a two tunnel three lane highway tunnel. The tunnel is in a north-east direction. The width of the tunnel chamber is 13.5 m, the height of the tunnel chamber is 7 m, and the maximum buried depth of the tunnel is about 363 m. The specific parameters of tunnel a and tunnel B are shown in Table 3.

Table 3. Specific parameters of the two tunnels

PARAMETER	TUNNEL A	TUNNEL B
EXCAVATION HEIGHT (M)	10.2	10.3
EXCAVATION WIDTH (M)	11.4	15.6
CONCRETE STRENGTH	C25	C25
ELASTIC MODULUS	29.5	29.5

(GPA)		
POISSON'S RATIO	0.2	0.2
THICKNESS OF SECONDARY LINING OF CLASS IV SURROUNDING ROCK (CM)	40	50
LONGITUDINAL THICKNESS OF SECONDARY LINING (M)	1	1
IRESISTANCE COEFFICIENT OF CLASS IV SURROUNDING ROCK (MPA/M)	350	400
BULK DENSITY (KN/M3)	22	25
FRICTION ANGLE	55°	60°

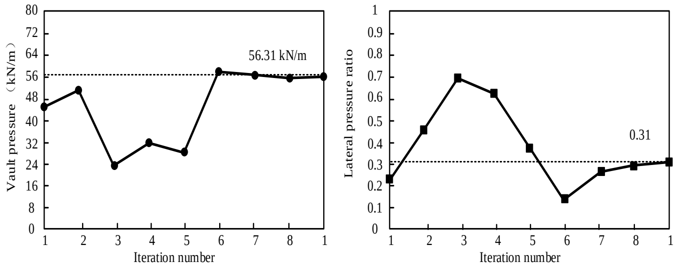
The quality and safety evaluation system of highway tunnel based on finite element analysis is used to analyze and evaluate tunnel a. the back analysis results of vertical load and horizontal lateral pressure coefficient of tunnel a are shown in Figure 6.



(a) Back analysis diagram of vertical load (b) Back analysis diagram of horizontal side pressure coefficient

Figure 6. Back analysis results of vertical load and horizontal lateral pressure coefficient of tunnel a

As can be seen from Figure 6 (a), the parameters are solved iteratively. With the increase of iteration times, the vertical uniform load value of tunnel a fluctuates continuously and finally converges after 7 iterations. The final convergence of the vertical uniform load value is 27.47 kn/m. Compared with the actual vertical uniform load value of 26.35 kn/m, the difference is 1.12 kn/m, and the error rate of finite element inversion analysis is 4.25%. As can be seen from Figure 6 (b), the horizontal lateral pressure coefficient curve of tunnel B rises continuously in the first three iterations, decreases continuously in the third to fifth iterations, and finally converges to 0.42 in the fifth iteration. Compared with the actual horizontal lateral pressure coefficient of tunnel B of 0.37, the difference is 0.05, and the error rate of finite element inversion analysis is 13.51%. The error between the back analysis and the actual data is lower than the accuracy threshold allowed by the actual engineering application, which shows that the finite element back analysis is feasible. The back analysis results of vertical load and horizontal lateral pressure coefficient of tunnel B are shown in Figure 7.



(a) Back analysis diagram of vertical load (b) Back analysis diagram of horizontal side pressure coefficient

Figure 7. Back analysis results of vertical load and horizontal lateral pressure coefficient of tunnel b

As can be seen from Figure 7 (a), through iterative solution of parameters, the numerical curve of vertical uniformly distributed load of tunnel B shows a trend of first decreasing and then increasing in the early stage of iteration, then converges in the sixth iteration and finally converges to 56.31 kn/m, while the actual vertical uniformly distributed load of tunnel B is 51.23 kn/m, with a difference of 5.08 kn/m. The error rate between the finite element inversion analysis results and the actual value is 9.92%, It is within the allowable error range of practical engineering application. As can be seen from Figure 7 (b), the horizontal lateral pressure coefficient curve of tunnel B gradually rises in the early stage of iteration, then decreases, tends to be stable in the seventh iteration, and finally converges to 0.31. Compared with the actual value of the horizontal lateral pressure coefficient of tunnel B of 0.26, the actual value increases by 0.05, and the error rate of the finite element inversion analysis result is 19.23%. Due to the small numerical base of the coefficient, the relative error is large, but the error is less than the allowable error threshold in the actual project, which proves that the quality safety evaluation system based on finite element analysis is feasible in the practical engineering application.

4 CONCLUSION

With the continuous improvement and expansion of China's expressway network, the application proportion of tunnel in expressway is higher and higher. The engineering quality of highway tunnel is directly related to the driving safety of the whole expressway line. In order to accurately evaluate the quality and safety of highway tunnel, this paper studies the construction of highway tunnel quality and safety evaluation system based on finite element analysis, uses the slotting method to test the concrete stress of the secondary lining structure, and establishes a finite element model to inverse analyze the load of the secondary lining structure, which can be used as the evaluation basis of the defective section of the secondary lining of highway tunnel. The test results show that the slotting method and finite element analysis are used to analyze the stress of the secondary lining structure. The error rate between the finite element numerical analysis data and the actual test data is 2.22%. The finite element analysis has high accuracy and can effectively analyze the actual stress of the secondary lining structure. The load parameters of tunnel a and tunnel B are analyzed by finite element inversion analysis. The error rates between the analysis results of vertical uniformly distributed load and the actual data are 4.25% and 9.92% respectively, and the error rates of horizontal lateral pressure coefficient are 13.51% and 19.23% respectively. The errors are within the acceptable accuracy range of actual tunnel engineering. Starting from the actual load of the secondary lining structure, the quality and safety evaluation of highway tunnel by finite element analysis can accurately evaluate the quality level of the secondary lining structure of the tunnel and provide reference for the safety supervision of highway tunnel.

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