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Retraction

Retracted: Numerical Simulation Research on Optimization of Large Deformation Control Parameters in Layered Slate Tunnel

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] L. Guo and Y. He, "Numerical Simulation Research on Optimization of Large Deformation Control Parameters in Layered Slate Tunnel," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 8337805, 7 pages, 2022.

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Research Article

Numerical Simulation Research on Optimization of Large Deformation Control Parameters in Layered Slate Tunnel

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In order to explore the deformation characteristics of layered slate tunnels under different dip angles of rock formations, a numerical simulation research method for optimization of large deformation control parameters of layered slate tunnels is proposed. The plane deviation, plane deformation, and DP parameters of the structure are obtained through the calculation mode. When studying the effect of overlapping rock masses on the stability of thick tunnels, the incidence angle of the rock structure is assumed to be zero. The estimated thicknesses of the dolomite limestone surrounding the tunnel are 0.3 m, 0.4 m, 0.5 m, 0.6 m, 0.7 m, 0.8 m, and 0.9 m, respectively. Select the vertical displacement to be analyzed as the result of the calculation. In order to study the influence of the structural slope on the tunnel stability, the thickness of the rock layer was 0.6 m, and the structural slopes of 5°, 15°, 30°, 45°, 60°, 75°, and 85° were used for simulation calculations. During on-site construction, focus on monitoring the tunnel section deformation before the secondary lining construction. Every 10-20 m, when the surrounding rock changes, the observation section of the enclosure convergence and vault settlement is arranged, and the peripheral displacement rate and the vault settlement rate are calculated according to the observed deformation. The results show that the vertical displacement of the top of the tunnel is generally in a “V” shape, that is, the maximum settlement in the tunnel; when the layer thickness is 0.3 m, the maximum vertical displacement of the rock layer is 7.2 mm, and the total settlement in the lining support tunnel is 8.23 mm. When the layer thickness is 0.9 m, the vertical displacement of the rock layer is 5.14 mm, and the total settlement in the lining support tunnel is 5.22 mm2; when the layer thickness was changed from 0.9 m to 0.3 m, the maximum vertical displacement of the rock layer increased by 140%, and the settlement at the vault increased by 158%. At this time, the focus of tunnel support is on both sides of the lining structure and the vault with large vertical settlement. The phenomenon that the section of YK51+032 first decreases and then increases due to the sudden appearance of mud in the surrounding YK51+040, resulting in increased short-term deformation. Only the ZK49+356 section at the entrance of the left line has a large deformation due to the thin overlying stratum, and other sections are relatively consistent, indicating the reliability of the calculation results.

1. Introduction

At this stage, the deformation control of tunnel construction is still unsatisfactory, especially the deformation problems of tunnels with high ground stress and weak surrounding rock are still relatively prominent; it is manifested as rapid deformation, large deformation, and long-lasting deformation, which is easy to cause the support to be dismantled and replaced due to intrusion or damage; and the construction safety risk is high, and it often leads to delays in construction period and increased investment, which brings great risks and challenges to tunnel survey, design, construction, and management [1]. The existing supporting technology is summarized and analyzed; construct a tunnel support system based on active deformation control, and study its support mechanism and key support technologies. In order to ensure the safe construction of railway tunnels, it is of certain significance to innovate the theory and method of railway tunnel support, and Figure 1 shows the solution of the online monitoring system for tunnel deformation. Aiming at the problem of tunnel deformation control, scholars have adopted methods such as field test, numerical simulation,

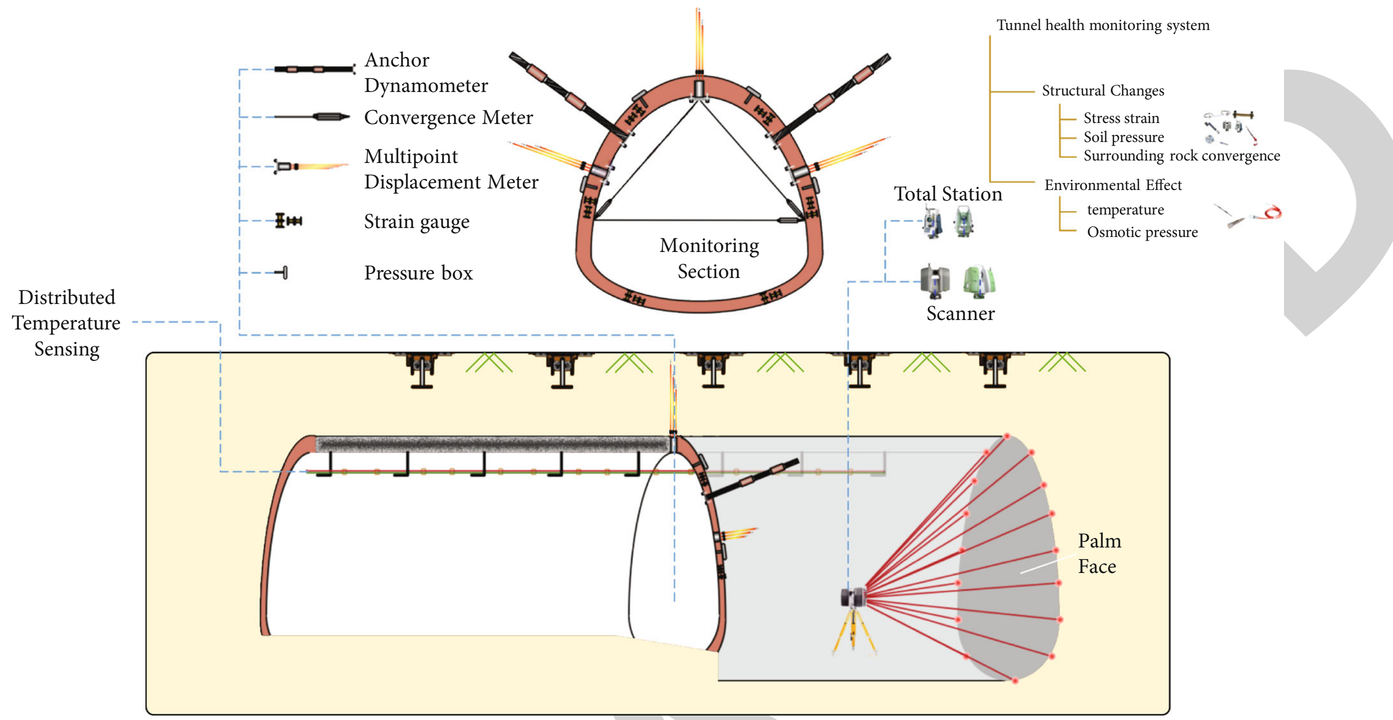

Figure 1: Solution of online monitoring system for tunnel deformation.

and theoretical analysis [2]. At present, there are certain deficiencies in the active control and support of surrounding rock deformation of railway tunnels in China, which are mainly manifested as follows: Railway tunnel support is generally a passive support system; at present, railway tunnel support generally emphasizes the deformation control of passive support members such as steel frames, and the support construction cannot effectively strengthen the surrounding rock. The support system based on passive support is suitable for tunnels with good surrounding rock, but under difficult conditions such as poor self-supporting capacity of surrounding rock and high in-situ stress, it is difficult to control deformation only by passive support, the supporting structure is easily deformed and damaged, and accidents such as tunnel collapse occur [3]. The concept of active support is still not unified; in the construction of railway tunnels for many years, the importance of active deformation control has been generally realized; and it is emphasized that active support should be used to prevent; the bearing capacity of the surrounding rock is fully utilized to control the deformation; and the supporting measures such as prestressed bolts (cables) and grouting reinforcement of the stratum have been extensively studied and applied. However, at present, there is no unified understanding of the support concept, application conditions, and scope of application of active deformation control [4]. The key technologies of active support system need to be further innovated. The effect of active support depends on high performance support materials. At present, the mechanical properties of supporting materials or components are generally low [5], which cannot give full play to the mechanical efficiency of supporting. High-performance shotcrete material technology, new anchorage material technology, and nondestructive testing technology of initial support construction quality should be studied to realize the rapid construction and timely effect of tunnel support.

2. Literature Review

In response to this research problem, Nedelescu, C. et al. proposed the concept of active control deformation. Bolt (cable) support and surrounding rock grouting are considered to be active support, while steel frame support, shotcrete support, and secondary lining are passive support [6]. According to the mechanism of tunnel support, PalAmit K. et al. divided the types of tunnel support into two categories, namely, active support and passive support. Passive support is passively applied to surrounding rock, and it is a support system that has relatively little effect on controlling the mechanical properties of surrounding rock [7]. Li, G. et al. put forward the mechanical support theory of soft rock engineering; systematically introduced the definition, basic properties, and continuity generalization of soft surrounding rock; and proposed the determination of deformation mechanics mechanism, support load determination, and support design method [8]. Luo, Y. et al. proposed the release-constrained balance method, and the deformation of surrounding rock is controlled from two aspects of releasing in-situ stress and optimizing support. The main measures for stress release are reserved deformation and advanced pilot holes; optimized support includes measures such as strengthening support, strengthening locking feet, timely closure, and dynamic reinforcement [9]. Wu, X. et al. proposed the classification of weak surrounding rock, tunnel section, and span classification and established a tunnel structure system with weak surrounding rock [10]. Li, C. et al. proposed a stability classification method for large section tunnels, and based on the face wedge failure mode and limit equilibrium theory, the advanced support design method of the tunnel full-section method construction face is proposed, which provides a theoretical guarantee for the tunnel full-section method construction face [11]. Liu, Q. et al., through their research on micro and macro NPR materials and structures, as well as their application in practical engineering, for the first time in the field of rock mechanics, the scientific problem of the concept and mechanical behavior of NPR support structure was proposed, and on this basis, it is proposed that "no matter what kind of engineering geological structure the rock mass has, after the NPR support is embedded, it will have the same constitutive relationship as the NPR bolt/cable" [12]. Wu, C. et al. studied the structure, constitutive model, and energy absorption characteristics of NPR anchor cables and used Flac3D to establish NPR anchor cable constitutive numerical simulation experiments, and the actual deformation characteristics of the NPR cable were fitted [13]. Zhang, C. et al. used Flac3D to simulate and analyze deep tunnels and their supports [14]. Matyushkin, I. V. and others proposed a variety of methods to simulate the mechanical behavior of surrounding rock and bolts, which promoted the application of Flac3D in tunnel engineering [15]. On the basis of the existing research, the author proposes nonlinear numerical simulation analysis to optimize the deformation parameters of the tunnel rock layer and uses the ANSYS finite element software to analyze the stress and deformation characteristics of the surrounding rock and foundation after the tunnel layer is excavated. There is obvious inhomogeneity between the displacement on one side of the rock layer slope which is smaller on the other side. Therefore, the roughness first increases and then decreases. The slope angle increases most obviously at 45° and gradually stabilizes when it is greater than 60°; the displacement of the arch and wall is less affected by the change of the slope. The design and construction of layered rock tunnel support should avoid accidents caused by excessive deformation and uneven deformation of the tunnel.

3. Methods

3.1. Computational Model. Since only the influence of surrounding rock changes was studied, a two-dimensional plane model was established. In order to reduce the adverse effect of boundary effects, the final size of the model was determined to be 100 m × 100 m. The thickness of the weak interlayer between rock layers is calculated as 2 cm. The origin of the coordinates is 10 m directly below the tunnel arch bottom, and the rest of the depth is converted into the pressure load of the corresponding layer thickness. The pressure load applied in the dip model is the self-weight load of the rock and soil in each half time. The lower boundary fixes the horizontal and vertical displacement, and the left and right only constrain the horizontal displacement [16].

3.2. Calculation Parameters. The physical and mechanical parameters of the selected materials are shown in Table 1, and the model calculation mode adopts the planestrain and D-P criteria.

3.3. Construction of NPR Anchor Cable Constitutive Model. The disadvantage of ordinary anchor cable relative to NPR anchor cable is that its deformation is small, and under the condition of large deformation or impact of surrounding rock, the anchor cable is damaged due to excessive deformation [17]. NPR anchor cable can not only adapt to large deformation surrounding rock, but also provide effective high constant resistance. It is necessary to redefine the anchor cable element (geometry, material parameters, and anchoring agent properties) using Fish language in Flac3D, the NPR anchor cable is an elastic-plastic body, its characteristics are described by a one-dimensional constitutive model, and its axial stiffness K can be expressed as

$$K = \frac{\mathrm{AE}}{L}, \tag{1}$$

where A is the reinforcement cross-sectional area (m^2), E is the elastic modulus (GPa), and L is the member length (m).

In Flac3D, the tensile yield strength F_t and compressive strength F_c of the anchor cable can be specified, and these two limits cannot be exceeded in the application of the constitutive model [18]. The parameters that govern the performance of NPR cables are tensile strength and tightening parameters, PR (normal) cables reaching their tensile strength limit due to pulling, or failure of the fasteners when installing NPR anchors. The strength of the anchor cable unit and the tightening agent is adjusted to be greater than the tensile strength of the anchor cable, which is rigidly connected with the surrounding rock, and the free end of the anchor cable is also adjusted to be rigidly connected with its surroundings, imitating stones and shelves. By adjusting the high deformation of the anchor cable when a constant resistance value is reached, it is possible to lengthen the anchor cable, filter the distance between the free end and the anchor end using the built-in Fish language, and control the anchor cable anchor force. When the anchor cable and the deformation value reach a predetermined value, the anchor cable unit is loosened [19].

4. Results and Analysis

4.1. Analysis of the Influence of the Thickness of the Layered Rock Mass on the Tunnel. Research of layered rock mass thickness effects on the stability of tunnel assumes that the rock structural plane angle is zero, and the tunnel surrounding rock dolomitic limestone strata thickness is, respectively, according to 0.3 m, 0.4 m, 0.5 m, 0.6 m, 0.7 m, 0.8 m, and 0.9 m. In the calculation results, select the vertical displacement for analysis. When the inclination of the rock formation is zero, layered rock mass can be regarded as a flexural member bearing uniformly distributed loads, and no matter how the layer thickness changes, the vault is the part where the vertical displacement of the tunnel changes the most [20]. Therefore, when the layered jointed rock layer

Table 1: Physical and mechanical parameters of main materials.

Category	Elastic modulus E/Gpa	Poisson's ratio ν	Severe$y/(kg.m^{-3})$	Friction angle $\varphi/(^\circ)$	Cohesion C/MPa
Mezzanine	0.185	0.24	1800	37	0.5
Surrounding rock	39.54	0.19	2702	—	—
Initial lining	20	0.2	2201	—	—
Second lining	25	0.2	2201	—	—

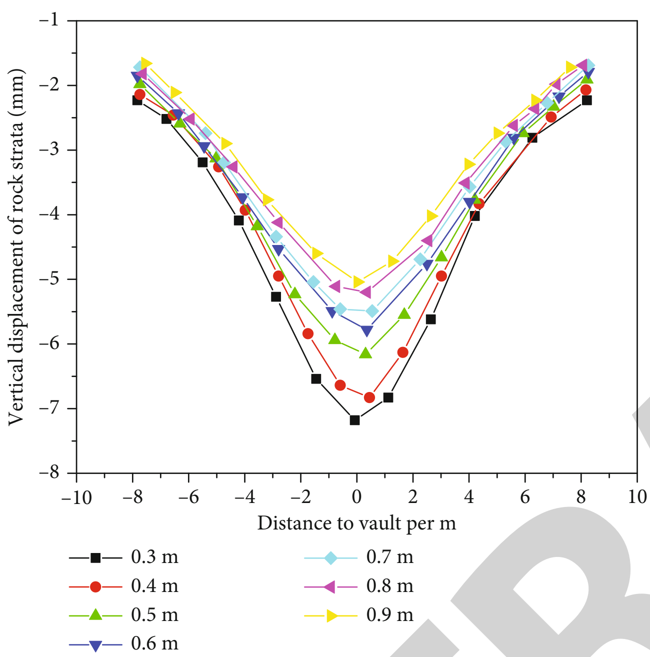

Figure 2: Vertical displacement curves of different thick rock layers.

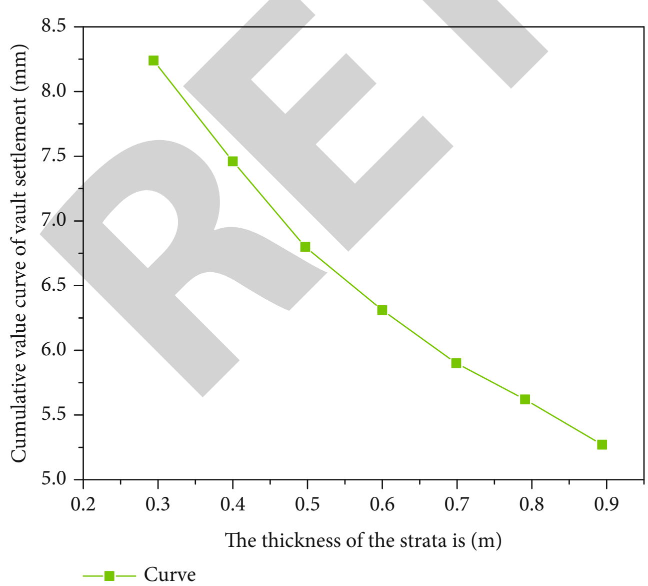

Figure 3: Cumulative value curve of settlement at the vault with different layer thickness.

is horizontal, the key point of lining support should be the dome position during tunnel excavation construction [21]. Select the vertical displacement of rock layers with different thicknesses and lining support arch tops with a horizontal length of 15 m directly above the vault, and draw the vertical settlement curves of the rock layers and the cumulative value of vault settlement at different layer thicknesses, as shown in Figures 2 and 3.

In Figure 2, the vault is the origin of the abscissa, and the left side of the vault is the positive direction, and the right side is the negative direction. The vertical displacement results ignore the settlement caused by the dead load of the model. It can be seen that the vertical displacement of the top of the tunnel is generally V-shaped, that is, the maximum settlement in the tunnel [22]. The total sag of the lining support frame is 5.22 mm2; from 0.9 m to 0.3 m, the maximum vertical displacement of the formation increased by 140%; and the settlement in the tunnel increased by 158%. It is clear that the stability of the tunnel is greatly affected by the thickness of the rock layers. As the thickness of the rock increases, the deformation of the upper part of the tunnel gradually decreases. If the thickness is 0.4-0.6 m, the vertical displacement decreases rapidly, but if the thickness is greater than 0.6 m, the displacement does not change much [23].

4.2. Analysis of the Influence of the Inclination Angle of the Rock Stratum Structure on the Tunnel. Since 0.6 m is the critical layer thickness for the speed of tunnel deformation, the rock layer thickness of 0.6 m is selected when studying the influence of the structural plane inclination angle on the tunnel stability, and the structural plane inclination angles are 5°, 15°, 30°, 45°, 60°, 75°, and 85 for simulation calculation. The displacement on one side of the rock stratum is smaller than that on the other side. The asymmetry of the displacement cloud map first increases and then decreases, and when the rock formation dip angle is close to 90°, this asymmetry will disappear. The deformation point with the largest settlement displacement for the lining structure is always the vault of the tunnel. It can be concluded that the dome position is the key point of lining support when the tunnel layer is excavated [24]. According to the distribution characteristics of the vertical displacement of the lining, six main points of the rock and lining around the tunnel are selected: the vertical displacement of the main point obtained from the tunnel and the corner. The bottoms of the left and right reverse arches and basement arches are shown in Figures 4 and 5.

From Figure 4, the vertical displacement and settlement of key points A (vault top) and F (vault bottom) decrease

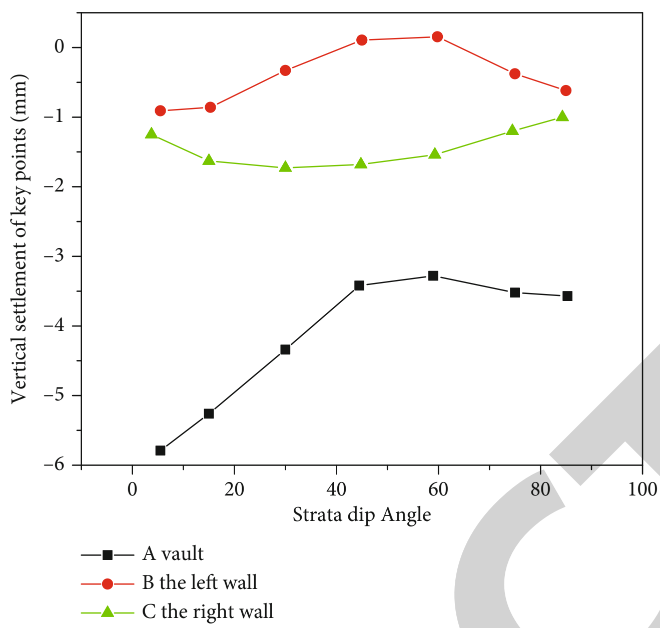

Figure 4: Vertical displacement curve 1 of key points.

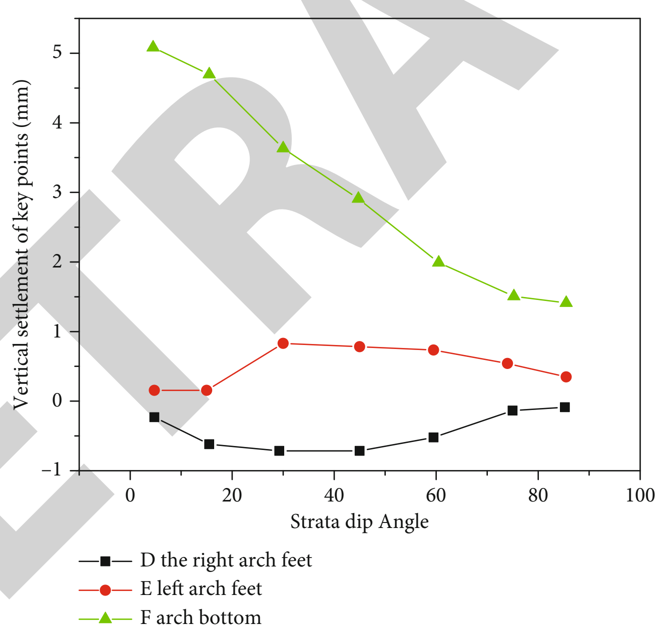

Figure 5: Vertical displacement curve 2 of key points.

with the gradual increase of rock inclination from 5° to 85°, especially when the inclination angle of the rock formation is from 5° to 45°, and the variation of the vertical displacement and settlement is large [25]. Moreover, with the increase of the inclination angle of the rock structure, the difference in displacement and settlement of key points at the same height first increases and then decreases, such as points B and C and points D and E. Since the inclination of the rock formation increases from the right side, in the calculation result, the inclination angle of the rock structure plane gradually increases from 5° to 45°, and the difference between the settlements on both sides increases and the displacement of the rock mass on both sides increase gradually asymmetrically; as a result, the relative sliding tendency between the rock layers on the left and right sides will also increase, and it may even lead to the damage of the lining structures. The inclination angle θ of the rock structure plane increases gradually from 45° to 85°, the difference between the settlements on both sides decreases, and the displacement of the rock mass on both sides decreases gradually asymmetrically. From Figure 4, it can also be concluded that when the tunnel thickness is constant and

Table 2: The distribution range of the convergence displacement rate of the BC survey line in some sections.

Station	(1.5)	(0.2, 1]	≤0.2
ZK49+356	8.5-8.9	8.09-8.19	8.19-9.24
ZK49+380	9.5-9.1	9.1-9.14	9.14-9.24
YK49+330	—	8.14-8.22	8.22-9.24
YK49+340	—	8.19-8.219	8.29-9.29
ZK51+020	8.2-8.28	8.28-9.29	9.29-9.23
ZK51+040	-8.14-8.17	8.09-8.19	8.19-9.16
YK51+032	9.22-8.24	8.17-9.24	8.24-9.22
YK51+050	—	9.09-8.18	8.18-8.24

Table 3: Distribution range of displacement rate of partial section vault.

Station	(1.5)	(0.2, 1]	≤0.2
ZK49+356	8.59-8.26	8.26-8.3	8.3-10.4
ZK49+380	9.59-9.11	9.11-9.17	9.17-10.28
YK49+330	8.14-8.18	8.18-8.23	8.23-10.5
YK49+340	8.19-8.26	8.26-8.29	8.29-10.1
ZK51+020	8.19-8.30	8.3-9.29	9.29-10.1
ZK51+040	8.09-8.17	8.17-8.29	8.19-10.3
YK51+032	8.17-8.24	8.24-8.3	8.3-10.13
YK51+025	9.1-9.21	9.21-9.24	9.24-10.13

the inclination angle gradually increases, due to the uneven settlement of the left and right sides of the tunnel lining structure, the rock dislocation leads to tension failure. Therefore, it is concluded that when the tunnel is excavated in the inclined, the focus of tunnel support is the two sides of the lining structure and the vault with large vertical settlement.

4.3. On-Site Monitoring and Analysis. During the on-site construction, focus on monitoring the tunnel section deformation before the construction of the secondary lining. Peripheral convergence and vault subsidence observation sections are arranged every 10~20 m, and the subsidence rate of the vault was calculated according to the observed deformation. Due to space limitations, the peripheral convergence and the distribution range of the vault displacement rate for one observation period of some sections are listed, as shown in Tables 2 and 3.

It can be seen from Tables 2 and 3 that, except for the YK51+032 section, the deformation rate of each section at the inlet and outlet gradually decreases with time. For the YK51+032 section, the phenomenon of first decreasing and then increasing is due to the sudden mud on the surrounding YK51+040, which causes the short-term deformation to increase. The layer thickness varies from 0.3 to 0.6 m, comparing the simulation results of tunnel vault settlement in Table 3, Figures 2 and 3, and Figures 4 and 5; only the ZK49+356 section at the entrance of the left line is greatly deformed due to the thin overlying strata; and other sections are relatively consistent, indicating the reliability of the calculation results.

5. Conclusion

The optimal monitoring and nonlinear numerical simulation analysis of tunnel rock deformation parameters are proposed, and the surrounding rock, basement stress, and deformation characteristics after excavation of layered dolomite limestone are analyzed by using ANSYS end element software. The vertical displacement of the tunnel arch is distributed in a "V" shape, and the maximum vertical displacement occurs in the tunnel. With the increase of the thickness of the rock layer, the maximum vertical displacement decreases and decreases with increasing rock thickness. The thickness of the rock formation is greater than 0.6 m. This is the defined critical thickness; it is clear that the displacement of the rock mass and lining around the slope tunnel will be nonuniform. The displacement of one side of the rock layer is smaller than that of the other side, and the unevenness increases first with the increase of the drop and decrease later. The angle is most obvious when the slope is 45° and gradually stabilizes when the slope is greater than 60°. The planning and construction of layered rock tunnel support should avoid accidents caused by excessive deformation and uneven deformation of the tunnel. In the future, it is necessary to analyze several factors causing large deformation of surrounding rock, study other factors and their relationship, disaster mechanism, quantitative evaluation index of each factor, and standard for determining the stability of surrounding rock. Further improvement is required. The creep characteristics and strength development law of soft surrounding rock under high in-situ stress and other conditions should be further studied. The rheological mechanism of soft surrounding rock tunnel and the constitutive model of soft surrounding rock needs to be also further studied, which is of great significance for the long life guarantee of tunnel in operation period.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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