Analysis of the influence of the full-section method in the construction of shallow-buried unsymmetrical tunnels

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Abstract: Aimed at the construction stability of the shallow-buried and biased exit section of the Georgia No.3 tunnel under construction. Using numerical simulation analysis method, the displacement and deformation of the unsymmetrical rock wall and the construction dynamic characteristics of the supporting structure are studied. It points out the weak links that should be paid more attention to in the construction. Numerical analysis results show that the side of the unbiased rock wall is most affected by the excavation, and the maximum tunnel displacement appears at the arch waist. The protection of this part should be strengthened during construction. The smooth implementation of this project can provide reference for similar highway tunnel construction.

1. Introduction
Highway tunnels can overcome the obstacles of height difference in mountainous areas and avoid large-scale excavation that can cause damage to the surface vegetation. Therefore, it is very common in traffic construction in mountainous areas with complex topography and geomorphology [1]. During the construction of the tunnel, the entrance section of the tunnel is often located in the shallow buried and biased section, the rock formation is relatively broken and the geological conditions are poor. Due to the numerous construction procedures, the surrounding rock and tunnel lining under the biased state bear complex forces, which is a major difficulty in the entire tunnel project [2-3].

Aiming at the construction stability of the shallow-buried unsymmetrical pressure tunnel entrance, Song Zhanping [4] used numerical simulation test analysis method to analyze the influence of different step distances on the deformation of surrounding rock and supporting structure during the step method construction of shallow-buried large-section tunnels. Zhu [5] used finite difference software to analyze the deformation of the tunnel and the supporting structure when the shallow buried and unsymmetrical double-arch tunnel was constructed with different excavation sequences. Zhang [6] used FLAC3D software to analyze the slope stability of the entrance section of the shallow-buried, unsymmetrical, large-section tunnel under different working conditions. An [7] analyzed the distance between different excavation surfaces of a shallow-buried, unsymmetrical, large-span tunnel, and obtained a reasonable distance through numerical simulation analysis.

At present, domestic and foreign scholars have conducted many studies on the construction stability of shallow buried bias tunnel portal construction, but the research on the full section method of shallow
buried bias large section tunnel is still relatively rare. This paper takes the exit section of the No.3 tunnel of Georgia's E60 highway as the engineering background, uses the finite element software MIDAS/GTS to establish a three-dimensional model, uses numerical simulation to analyze its construction stability, and points out the dangerous parts that need attention in the construction. It can provide a reference for similar road tunnel construction.

2. Project overview

2.1 Engineering geology of Tunnel No.3

According to geological survey data, the Khevi-Argveta section of the E60 route is located in the middle of the Georgian block, between the Greater Caucasus in the north and the Lesser Caucasus in the south (Fig.1). The mountains that the project passes through are divided by the canyon formed by the Dzirula Gorge and the Kvirila River and its tributaries, resulting in fragmented terrain. The stratum that the tunnel passes through is the intrusive rock and metamorphic rock that constitute the Proterozoic crystalline basement. They are represented by pink and gray granite and quartz gneiss, and their main characteristics are hard. The surrounding rock grade is III~IV.

![Fig.1. Plane location of Tunnel No.3](image)

2.2 Construction overview of No.3 Tunnel

Georgia No.3 Tunnel DK5+179-5+239.095 is the exit section of the tunnel, and the tunnel support parameters are shown in Fig.2.

![Fig.2. Tunnel section size and support parameters](image)

The displacement of the tunnel is relatively large, so the disturbance between the tunnel construction at the exit section is small, mainly considering the bias pressure disturbance during the construction of
the TA tunnel. According to the engineering geological conditions of the No.3 tunnel, the tunnel site area is mainly composed of poor rock masses (RMR III-IV, GSI 35-45) with medium to high fractures. Therefore, the B0 section is used for the exit section construction. In this case, in order to give full play to the self-supporting role of the rock structure and minimize the repeated disturbance to the surrounding rock, the tunnel construction shall adopt mechanical means to carry out full section excavation with a maximum length of 2.4 meters and make preliminary lining according to the design and specification requirements.

3. Numerical model

3.1 Calculate model parameters
According to the topography and geological conditions of the exit section of Tunnel No.3, the DK5+016.12~5+239.095 section is taken as the research object to establish a three-dimensional numerical analysis model as shown in Fig.3. According to the actual situation of the strata and mountains, the size of the model is about 110 m in the horizontal direction (X-axis direction), about 130 m along the tunnel axis (Y-axis direction), and the vertical direction (Z-axis direction) from the bottom of the tunnel to the distance of the lower boundary is 35 m. The stratum where the tunnel is located is a gray quartz gneiss stratum, which is classified into grade III-IV surrounding rocks according to the surrounding rock formations. Based on the tunnel construction experience and using the finite element software MIDAS-GTS to analyze the rock mass-tunnel overall analysis model, the surrounding rock adopts the Mohr-Coulomb elastoplastic constitutive model, and the lining adopts the linear elastic constitutive model. The surrounding rock of the formation adopts 3D solid elements, and the primary support and second lining adopt 2D plate elements for simulation.

According to the influence of the actual environment, combined with the relevant parameter reduction theory, the calculation parameters of various materials in the model are shown in Table 1.

| Table 1 Material parameters of the model |
|-------------------------------|-----------------|---------|-------|-------|-------|-------|
| material                      | thickness /cm   | Unit    | E(GPa)| γ(kN/m³)| μ    | C(MPa)| ϕ(°) |
| Gneiss (III-IV level)         | -               | entity unit | 1.0  | 25    | 0.3  | 100  | 54   |
| C30 shotcrete initial support | 20              | Plate unit | 30.0 | 24    | 0.2  |      |      |
| C35 Reinforced concrete secondary lining (invert) | 80 | Plate unit | 31.5 | 25    | 0.2  |      |      |
| C35 reinforced concrete secondary lining (vault) | 65 | Plate unit | 31.5 | 25    | 0.2  |      |      |
3.2 Dynamic simulation of model construction
The tunnel project shared 114 construction stages for simulation. The first 8 steps are slope treatment before tunnel excavation, as well as slope excavation and spray mixing. The simulation of tunnel excavation was followed. The tunnel entrance section AT and TA are simultaneously excavated by the full-section method of 1.5m each time. After the section is excavated, the primary support spray mixing is carried out immediately, and the second lining construction is carried out after the entire tunnel excavation is completed.

4. Numerical results and analysis

4.1 Analysis of displacement and deformation of rock wall under bias
A monitoring section is arranged every 10m for the displacement of the biased rock wall, as shown in Fig.4. CD-1~CD-4 are the monitoring points for the lateral displacement of the biased rock wall of the TA tunnel. See Fig.5.

![Fig.4 Layout of measuring points in the tunnel](image)

According to the comparison of the lateral displacement and deformation distribution curves in Fig.5, the deformation laws of CD-1~CD-4 are basically the same. With the removal of the last grade of slope soil, the four measuring points all have large sudden changes. And the mutation value of CD-1~CD-3 increases with the increase of the buried depth of the measuring point, and the mutation value of CD-3 is 3.19mm, the maximum of the four measuring points. Since CD-4 is close to the uphill position of the AT tunnel, the mutation value bound by the uphill position is reduced. Affected by the construction process of the TA tunnel, the deformation values of CD-1~CD-4 gradually increased gradually, but the final deformation of the arch waist still appeared in CD-3 with a value of 4.83mm. In summary, the CD-3 position and its front and rear sections should be properly protected against slopes.

![Fig.5 Displacement curve of TA rock wall measuring point](image)
4.2 Horizontal convergence analysis of initial support
The lateral deformation of the support structure after the construction of the support scheme is shown in Fig.6. According to the comparison of the deformation in the figure, under the influence of bias pressure, the deformation distribution of the initial support structure caused by the support scheme is different ("positive" means the positive displacement in the X-axis, and "negative" means the negative displacement in the X-axis). The deformation of the arch waist AT the DK5+210 position in the middle of the cross-pitch section of TA tunnel and AT tunnel is the highest. Also affected by bias pressure, the arch waist deformation AT the side of TA tunnel AT DK5+180 is the maximum value of this tunnel, and DK5+180 and DK5+210 of TA tunnel are the typical sections of the interval formation deformation study.

Therefore, the lateral displacement curve of the arch waist of the two sections is shown in Fig.7. The change law of the arch waist curve is not consistent due to the difference in construction steps. The first sudden change of the arch waist deformation of the TA tunnel characteristic section was affected by the excavation, the soil was removed and the stress was released, resulting in a deformation of 0.73mm. With the construction of the TA tunnel to the characteristic section of the AT tunnel, the deformation of the AT tunnel's arch waist gradually increased from -1.61mm to -2.16mm. However, the abrupt deformation of the two tunnels is mainly affected by their own excavation. The final deformation value of the arch waist of the TA tunnel is slightly larger than that of the AT tunnel by 0.45mm.

5. Conclusions
This article takes Georgia No.3 Tunnel as the engineering background. Then we made a comparative...
analysis and concluded as follows:

1) When analyzing the rock wall of the TA tunnel, numerical simulation shows that the deformation values of the four measuring points CD-1~CD-4 on the rock wall are most affected by the excavation. After that, it increased slowly with the progress of TA tunnel construction, and the final deformation value appeared at CD-3. Therefore, the weak link of the outer rock wall of the TA tunnel in Georgia's No.3 tunnel section and the corresponding reinforcement measures are determined.

2) Through the comparative analysis of numerical simulation, the maximum lateral displacement of the TA and AT tunnel supporting structures at their characteristic sections all appear at the arch waist position. This is due to the combined effects of the external squeezing of the surrounding rock on the sidewall of the tunnel and the large amount of water in the tunnel, resulting in uneven stress distribution in the surrounding rock. Although the deformation of the surrounding rock is within a reasonable range from the perspective of the displacement of the surrounding rock, attention must be paid to the support of the arch waist during construction to ensure the safe and smooth construction of the project.

3) The final deformation value of the TA tunnel is slightly larger than that of the AT tunnel, indicating that the side of the unbiased rock wall is more affected by the excavation. With the construction of the TA tunnel to the characteristic section of the AT tunnel, the deformation of the arch waist of the AT tunnel increases. It is explained that the tunnel that is excavated later will affect the tunnel that was excavated first to a certain extent, and its force and deformation will become larger.

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