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Research Article

Research on Construction Control Technology of Large-Span and Small Clear Distance Underpass High-Voltage Line Tunnel

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Abstract: Hanping tunnel is a control project of national highway 310 Dahejia to Qingshui highway project. It needs to cross a 330kV high-voltage transmission line under the condition of small clear distance, which requires high construction requirements. In view of the difficulties such as shallow buried depth of tunnel and small clear distance between tunnel and tower of high-voltage line, multiple excavation blasting method is adopted, and smooth blasting, charge quantity control and damping hole setting are comprehensively used to reduce the impact on the tower and structure of high-voltage line. In order to ensure the smooth progress of the project, the large-scale finite element analysis software is used to simulate the whole excavation project. The influence of the full-section method and the middle partition wall method (CD method) on the surrounding rock and the high-voltage electric tower is compared. It is found that the CD method can effectively control the displacement of the surrounding rock and the tower on it and the uneven settlement.

Keywords: Large-span tunnel; High-voltage tower; Construction control

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1 Introduction

The construction process of the tunnel is a process of rebuilding the balance between the rock mass and the tunnel. In this process, it will inevitably bring about certain impact on surrounding existing buildings with the change in stress. Minimizing the adverse effects caused by the construction and ensuring the safety and performance of existing buildings are important considerations in tunnel construction. High-voltage transmission

lines play an extremely important role in the national grid. They are the main force for power transmission to remote areas. Once they are affected by tunnel excavation, they will tilt and subside, which will directly affect the realization of their power transmission functions, leading to power problems in some areas[1,2]. In such cases, the strategy of avoidance is generally adopted to ensure the safety of high-voltage lines. However, due to the limitation of line selection, some tunnels need to be close to or pass through high-voltage towers. In view of this, it is necessary to carry out the whole-process construction simulation and monitoring of the situation of large-span and small-distance under-passing high-voltage lines to ensure the safety of construction.

Currently, some experts have conducted systematic research on this aspect. Regarding the highway tunnel underpassing high-voltage lines, Hu

Huanxiao and Shen Zenghui conducted construction simulations using the Lijiachong highway tunnel as an example, and explored the method of surface grouting to control the effects of high-voltage tower subsidence[3,4]. Yang Junsheng and others conducted in-depth research on large-section under-passing high-voltage line towers from the aspects of technology and scheme, analyzed the pros and cons of various construction strategies, and laid a solid foundation for subsequent construction research[5,6]. Other scholars delve into numerical analysis to study the influence of various construction methods on the deformation of the towers and various internal forces, so as to reveal the deformation and failure of the towers[7,8]. This type of research is mostly aimed at large-section separated highway tunnels. For large-span and small-distance tunnels, there is still a lack of a complete set of construction simulation and research of control technology. For this, this paper takes the Hanping tunnel control project on National Highway 310 as an example and analyzes the impact of large-span and small-distance tunnel construction on the high-voltage iron tower in combination with numerical simulation.

2 Project Overview

The Hanping Tunnel is located in Hanping Village, Qingshui Town, Xunhua County. It is a key project of the National Highway 310 Dahejia to Qingshui Highway Project. It is located in the middle and lower section of the left bank slope of the Yellow River. The Hanping Tunnel is a short tunnel, and the tunnel construction boundary adopts the same width as the roadbed section: hard road shoulder entrance design. The maximum depth of the left tunnel is about 57m, and the maximum depth of the right tunnel is about 49.5m. The excavation width of a single tunnel is about 15.6m, and the design distance between the left and right tunnels is 15.68m. It is a small-distance tunnel and adopts composite lining.

The left line of the Hanping Tunnel passes through the high-voltage tower, and the minimum vertical clearance between the tunnel and the high-voltage tower is 53m. Figure 1 shows the layout of the lining structure of the tunnel underneath the high-voltage tower section. The surrounding rocks are strong and moderately weathered conglomerate and sandstone. The joints and fissures are relatively developed, and the rock bodies are relatively fragmented. It has a fractured block structure or a medium-to-large thick-layer structure. The direction of the rock strata intersects the direction of the tunnel at about 25°, and the dip angle is between 5~10°. The type of groundwater is bedrock fissure water with weak water richness.

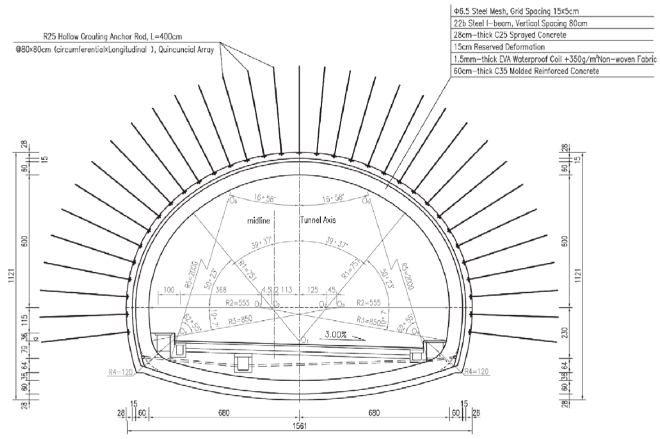


Figure 1. Schematic of the Tunnel Lining Layout

3 Numerical Simulation of Construction Method

In order to minimize the impact on the high-voltage tower, the CD method was used for excavation, and compared with the full-section excavation method to obtain the construction control effects. In order to evaluate the most unfavorable stress and deformation state of the existing building structure during the tunnel excavation process, the excavation process in the simulation calculation was consistent with the actual situation. The specific simulation steps of the CD method were: the excavation of the upper right pilot tunnel of the left tunnel, the excavation of the lower right pilot tunnel of the left tunnel, the excavation of the upper left pilot tunnel of the left tunnel, the excavation of the lower left pilot tunnel of the left tunnel, the excavation of the upper left pilot tunnel of the left tunnel, the excavation of the lower left pilot tunnel of the right tunnel, the excavation of the upper right pilot tunnel of the right tunnel, and the excavation of the lower right pilot tunnel of the right tunnel; while a program was used to simulate a full-section excavation for the full-section excavation method.

The load of the transmission tower is related to the selection of tower type, conductor cross-section, meteorological conditions, span, and geographic location. According to relevant design and construction experience, the weight of the transmission tower can be taken as 12t, plus the conductor load and other components without heavy weight, the total calculated load was taken as 20t here considering the most unfavorable conditions.

The foundation of the transmission tower is four independent foundations, and the distance between the foundations is about 5.5m. During the construction, the vertical load of the transmission tower is taken as the average load, and the load is 8kN/m^2.

In the simulation process of tunnel excavation, the lining adopted beam units. Each structure size of the model adopted a two-dimensional plane finite element model according to the design parameters, as shown in Figure 2. Boundary conditions of the model: the bottom side is a two-way displacement constraint, the side is a normal phase displacement constraint, and the top is a free-surface except for the foundations under load.

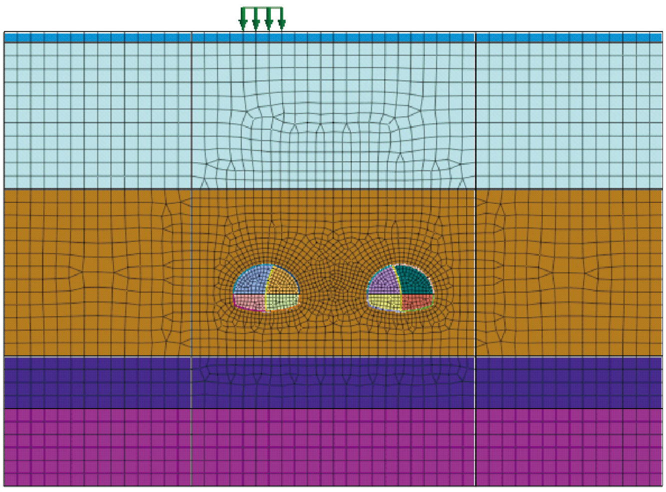
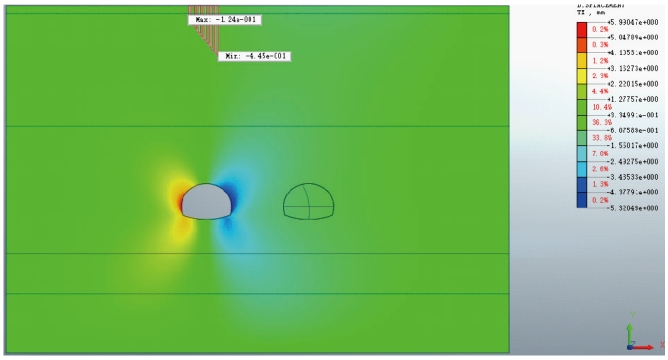
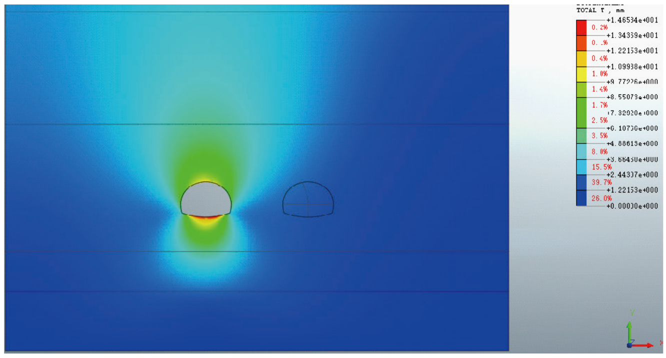


Figure 2. Diagram of Calculated Model

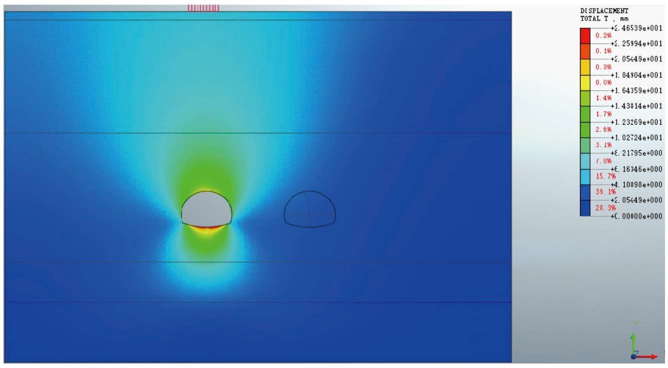
In order to compare the impact of the two construction methods on the high-voltage tower during the construction process, the surrounding rock and structural displacement of the left chamber constructed using full-section excavation and CD method are shown in Figure 3 below(Table 1).



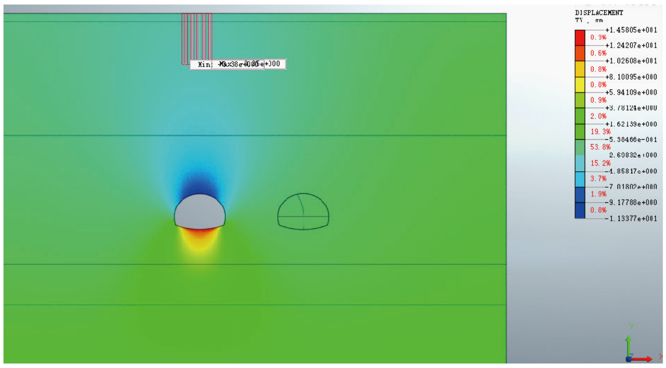
(a)Total Displacement with CD Method



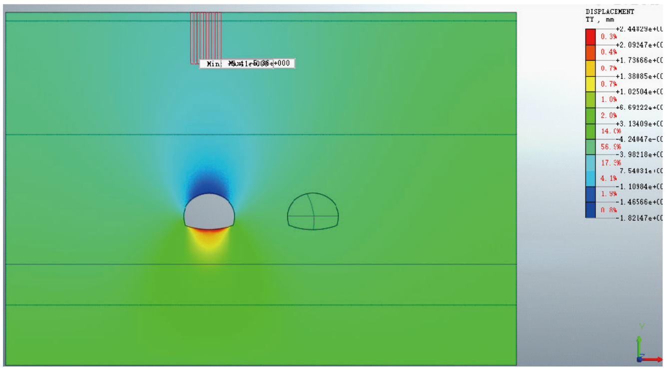
(b)Horizontal Displacement with CD Method



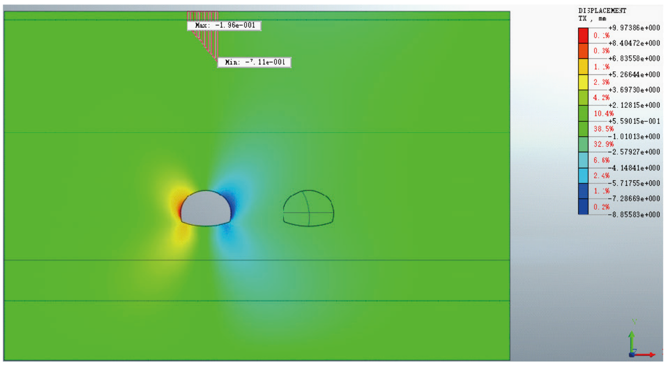
(c)Vertical Displacement with CD Method



(d)Total Displacement with Full-section Method



(e) Horizontal Displacement with Full-section Method



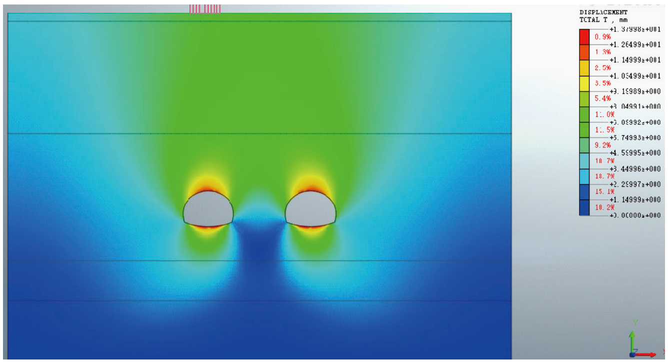
(f) Vertical Displacement with Full-section Method

Figure 3. Distribution Map of the Displacement of Surrounding Rocks

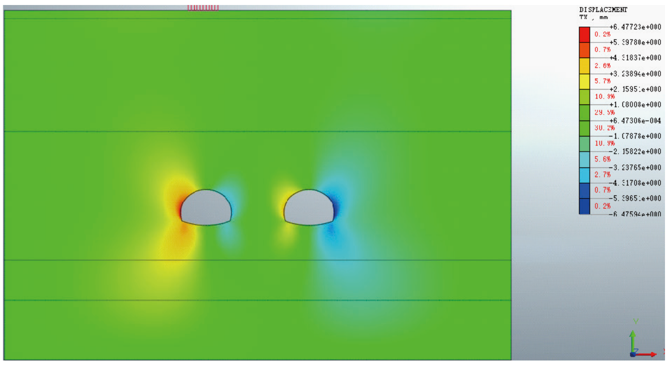
Table 1. Statistical Table of the Maximum Displacement of Key Sites

Construction ethod	Location	Horizontal Displacement (mm)	Vertical Displacement (mm)
CD Method	Surrounding Rocks	6.0	14.6
	Foundations	0.4	3.4
Full-Section Method	Surrounding Rocks	10.0	24.4
	Foundations	0.7	5.4

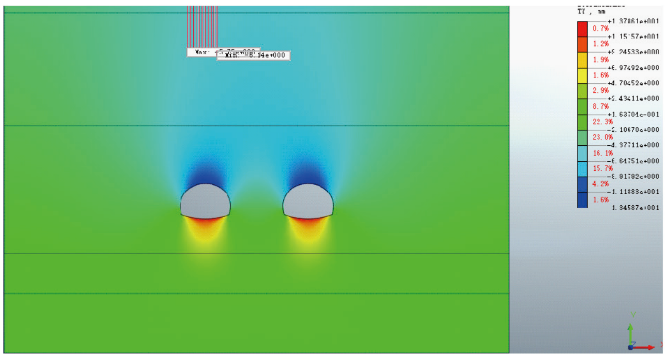
After the CD method construction of the left tunnel was completed, the maximum horizontal displacement of the rock around the cave was 6.0mm, the maximum settlement was 11.2mm, the maximum uplift was 14.6mm, the maximum horizontal displacement of the structure was 0.4mm, and the maximum foundation subsidence was 3.4mm, and the uneven subsidence was 0.03mm. During the tunnel excavation, the deformation of the foundation was small, which meets the requirements of the "Technical Regulations for the Design of Overhead Transmission Line Foundation" (DL/T 5219-2014) to control the maximum foundation inclination at 0.006. With full-face excavation, the maximum horizontal displacement of the surrounding rock was 10.0mm, the maximum settlement was 18.2mm, the maximum uplift was 24.4mm, the maximum horizontal displacement of the structure was 0.7mm, the maximum foundation subsidence was 5.41mm, and the uneven subsidence was 0.04. mm. The displacement data of full-section excavation were greater than that of the CD method construction. In order to further study the influence of the construction method on the high-voltage electric tower during the construction process, the surrounding rock and structure displacement after the excavation was completed are shown in Figure 4 below(Table 2).



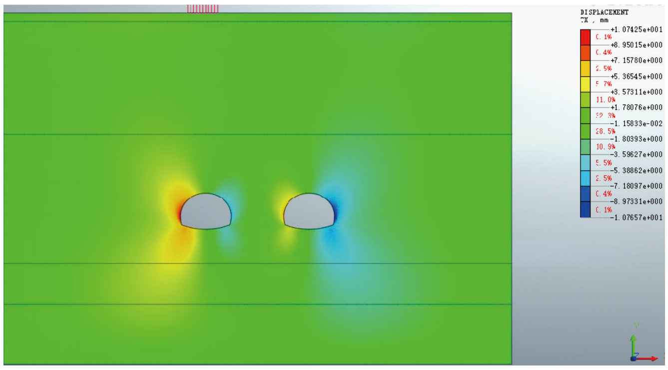
(a)Total Displacement with CD Method



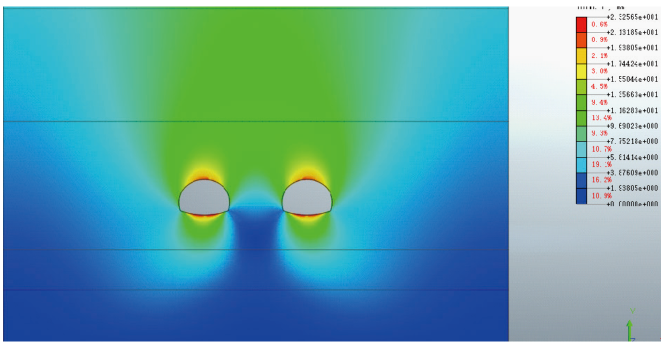
(b)Horizontal Displacement with CD Method



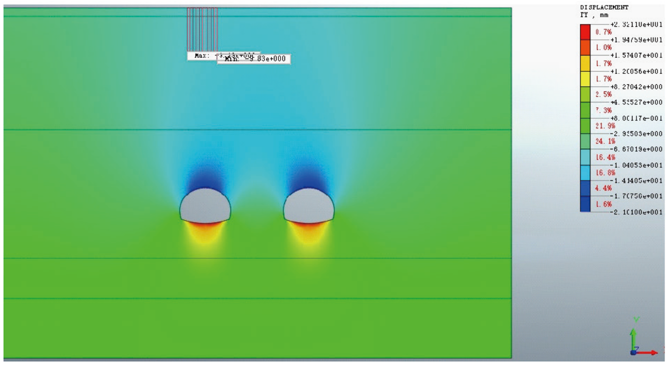
(c)Vertical Displacement with CD Method



(e) Horizontal Displacement with Full-section Method



(d)Total Displacement with Full-section Method



(f) Vertical Displacement with Full-section Method

Figure 4. Distribution Map of the Displacement of Surrounding Rocks

Table 2. Statistical Table of the Maximum Displacement of Key Sites

Construction Method	Location	Horizontal Displacement (mm)	Vertical Displacement (mm)
CD Method	Surrounding Rocks	6.5	13.8
	Foundations	1.0	6.1
Full-Section Method	Surrounding Rocks	10.8	23.2
	Foundations	1.6	9.8

After the excavation was completed, the maximum horizontal displacement of the rock around the cave was 6.5 mm, the maximum subsidence was 13.5 mm, the maximum uplift was 13.8 mm, the maximum horizontal displacement of the structure was 1.0mm, the maximum foundation subsidence was 6.1mm, the minimum foundation subsidence was 5.8mm, and the uneven subsidence was 0.39mm. During the tunnel excavation process, the foundation deformation was less, which meets the requirements of the "Technical Regulations for Basic Design of Overhead Transmission Lines" (DL/T 5219-2014) to control the maximum foundation inclination at 0.006. Although the full-section excavation also meets the specification requirements, the horizontal displacement of the surrounding rock was 4.3 mm greater than the CD method, and the vertical displacement was 10.6 mm greater. The uneven subsidence of the high-voltage electric tower foundation reached 0.64 mm, which was much greater than that of the CD method. From the perspective of the whole construction process, the CD construction method can well control the deformation of the surrounding rock and the foundation of the chamber, and reduce the impact of tunnel construction on the high-voltage electric tower.

4 Conclusions

The Hanping small-distance tunnel underpasses high-voltage line, and the construction requirements of the tunnel are extremely high. In order to ensure the safety of the 330KV high-voltage line tower above it, a series of safety assurance measures were formulated during the construction, controlling from the two aspects of the displacement of the chamber surrounding rock and the subsidence of the high-voltage tower. In order to ensure the smooth progress of the construction, the large-scale finite element program GTS was used to carry out the full-scale construction simulation of the whole process. Through simulation analysis, it was found that using the CD method for construction to control the displacement of the surrounding rock and the subsidence of the high-voltage electric tower, the displacement of the rock can be controlled within 15mm, and the maximum subsidence of the high-voltage iron tower is 6.1mm, which meets the relevant requirements of the regulation. It is recommended to use the CD method to reduce the area of a single excavation in the construction of such large-span and small-distance underpassing high-voltage tunnels. In order to further reduce the impact caused by blasting, use smooth blasting and control the single charge amount to protect the safety of the high-voltage transmission lines.

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