Analysis on Ground Surface Settlement of Newly Built Tunnel under Existing Expressway

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ABSTRACT

Relying on the Beihuan tunnel project, the numerical calculation of the excavation of the newly built tunnel down-traversing the existing expressway is carried out. The ground settlement deformation law of the expressway under different excavation schemes is analyzed, and the applicability of Peck formula in the calculation of the influence scope of ground settlement is discussed. The results show that: the numerical calculation of surface settlement range corresponds to Peck formula predicted result well.

Keywords: Peck formula, surface settlement, lateral settlement.

THE INTRODUCTION

The construction of the new tunnel under the existing expressway will inevitably cause disturbance to the formation, which will inevitably produce different degree of land subsidence[1].

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The Peck method is undoubtedly one of the easiest ways to predict the surface displacement caused by tunnel excavation. It is also the most widely used method up to now. However, since the Peck method is based on the empirical formula proposed by the measured data in the limited area, the mechanism of predicting the displacement of the formation is not clear. The applicability and scope of application also need further analysis.

According to the numerical calculation of the Beihuan tunnel, the applicability of the empirical method of the Peck formula to affect the surface subsidence based on the theoretical calculation and numerical simulation, the influence of the new tunnel construction scheme on the existing expressway is studied, and the deformation law of the expressway surface under different excavation schemes is discussed, which is of great significance to guide the similar construction.

**PECK FORMULA AND PARAMETERS**

The Beihuan tunnel is located in the low mountainous area. The terrain is fluctuating, the gully is horizontal and vertical, and the natural slope is about, the top of the tunnel is developed, the mountain bedrock is exposed, the gentle and gentle slope is mostly monsoon loess, difference. The formation of the tunnels through the formation of the Quartet of the new system artificial fill sandy loess, alluvial sandy loess, sand, gravel sand, the Quaternary system on the new system of sandy loess, Tertiary in the new mud Sandstone.

The Beihuan tunnel under the highway section, V-level rock, length 100m, depth of about 8.0m, the surface is artificial fill, under the class III hard soil. The stratigraphic displacement curve caused by excavation of underground tunnels is commonly used as a settling tank. The deformation of the subsidence is manifested in the way that with the excavation of its subsidence trough, Peck thinks that the settlement of the strata is mainly caused by the loss of the strata, the subsidence curve appears as a Gaussian curve similar to the normal distribution. The transverse settlement Peck curve is expressed by the Peck formula:

\[
    w(x) = w_{\text{max}} \exp\left(-\frac{x^2}{2i^2}\right) \tag{1}
\]

\[
    i = \frac{H + R}{\sqrt{2\pi} \tan (45^\circ - \varphi/2)} \tag{2}
\]

\[
    w_{\text{max}} = \frac{V_i}{i \sqrt{2\pi}} \approx \frac{V_i}{2.5i} \tag{3}
\]
\( w(x) \) - the distance from the center of the tunnel to \( x \) at the surface sedimentation (mm);
\( x \) - the distance from the centerline of the tunnel
\( w_{\text{max}} \) - the maximum settlement (mm) at the center line of the tunnel;
\( i \) - the distance coefficient of the surface subsidence trough, the distance from the center of the tunnel to the bending point of the sedimentation curve, half of the width of the settling tank can be taken as \( 2.5i \);
\( H \) - the thickness of the tunnel dome cover;
\( R \) - the tunnel equivalent radius;
\( \varphi \) - the internal friction angle;
\( V_i \) - the amount of formation loss caused by tunnel excavation.

If the definition of formation loss rate (Volume Loss) for the surface subsidence area and tunnel excavation area A ratio, generally expressed as a percentage. The amount of formation loss caused by tunnel excavation. The thickness of the roof cover of the Beihuan tunnel is 8m, the friction angle of the formation is 4.84m, the tunnel excavation area is 73.6m2, and the formation loss rate is 0.162%.

Calculated,
\[ i = 8.87 \quad (4) \]
\[ w_{\text{max}} \approx \frac{V_i}{2.5i} = 5.38 \quad (5) \]

The Peck curve can be expressed as:
\[ w(x) = -5.38 \exp \left( -\frac{x^2}{2 \times 8.87^2} \right) \quad (6) \]

The surface subsidence curve after tunnel excavation is shown in Figure 1.

**FIGURE 1.** Prediction of surface lateral settlement curves by Peck formula.
NUMERICAL SIMULATION OF DIFFERENT EXCAVATION SCHEMES

The horizontal width of the model is 120 m, and the distance from the lower part of the vertical tunnel is 5 times the height of the tunnel, and the calculation model above the tunnel is taken as the highway pavement. The model geometry is shown in Figure 2.

Numerical calculation using geotechnical engineering numerical calculation software-FLAC3D. The rock mass and support structure are simulated by FLAC3D solid element. Three-dimensional numerical model calculation grid and the excavation of the calculation grid shown in Figure 3.

The primary lining is modeled by solid element, and the second liner is modeled by shell element. The tube is simulated by beam element, and the bolt is modeled by cable unit. The physical mechanics parameters are shown in Table 1.

![Figure 2. Calculates the Model Geometry.](image1)

![Figure 3. Numerical Computation Model Grid.](image2)

**TABLE 1. Physical mechanics parameters.**

|                     | Elastic Modulus /GPa | Poisson's ratio | Cohesion /MPa | Friction angle |
|---------------------|----------------------|-----------------|----------------|----------------|
| Surrounding rock    | 1.5                  | 0.3             | 0.45           | 30             |
| Initial support     | 36.6                 | 0.2             |                |                |
| Secondary lining    | 33.5                 | 0.2             |                |                |
| Tube shed           | 210                  | 0.26            |                |                |
| Anchor              | 210                  | 0.69            |                |                |

During the calculation, the Mohr-Coulomb model is used to simulate the tunnel rock. The elastic model simulates the initial support concrete and the shell unit simulates the secondary lining. The effect of the initial support of
the medium-sized steel arch is considered by the equivalent method. During the numerical calculation, three kinds of excavation schemes were simulated, including Full face excavation method, Benching tunneling method and Tri-bench excavation method.

According to the Peck formula, the maximum settlement of the surface rock after tunneling is about 5.38mm, and the influence range is within 20m of the tunnel centerline. The distribution of the surface subsidence curves at different depths of the overlying strata of the tunnel is obtained by the numerical simulation calculation results, as shown in Figure 4.

CONCLUSION

The construction of the Beihuan Tunnel destroyed the stability, resulting in the settlement of the upper freeway, especially in the vicinity of the tunnel vault. Based on the theoretical calculation and numerical simulation, the settlement and deformation law of the tunnel under different excavation schemes are obtained. During the three numerical excavation schemes, the maximum settlement value of the tunnel is gradually reduced as the location of the overburden is different from that of the tunnel vault. According to the monitoring data of surface subsidence, it is shown that the apparent subsidence troughs are generated on the surface during the excavation of shallow buried tunnels. Compared with the numerical results, the influence of surface subsidence has a certain degree of coincidence with the prediction range of Peck formula.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support from Guizhou Provincial Science and Technology Department (QKH-SY[2015]3055). The authors also gratefully acknowledge the support provided through the research project of
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