The analysis of creep characteristics of the surrounding rock of the carbonaceous rock tunnel based on Singh-Mitchell model

Junhui Luo¹*, Decai Mi¹, Qiongyao Ye¹, Shengqiang Deng¹, Fuquan Zeng², Yongjun Zeng ²
¹Guangxi Communications Planning Surveying and Designing Institute Co., Ltd, Nanning 530029, China
²Guangxi Vocational and Technical College of Communications, Guangxi, Nanning 530029, China

*Corresponding author e-mail 83569159@qq.com

Abstract. Carbonaceous rock has the characteristics of easy disintegration, softening, swelling and environmental sensitivity, which belongs to soft surrounding rock, and the deformation during excavation and long-term stability of the surrounding rock of carbonaceous rock tunnel are common problems in the construction of carbonaceous rock tunnel. According to the above, the Monitor and measure the displacement, temperature and osmotic pressure of the surrounding carbonaceous rock of the tunnel of Guangxi Hebai highway. Then it based on the obtaining data to study the creep mechanism of surrounding rock using Singh-Mitchell model and predict the deformation of surrounding rock before the tunnel is operation. The results show that the Singh-Mitchell creep model can effectively analyse and predict the deformation development law of surrounding rock of tunnel without considering temperature and osmotic pressure, it can provide reference for the construction of carbonaceous rock tunnel and the measures to prevent and reinforce it.

1. Introduction
Carbonaceous rock is a kind of clay rock, the composition is complex, mostly black, in addition to the clay minerals, but also contains many clastic minerals and autogenous minerals, with page-like or lamellar-like bedding, which typical rocks have carbonaceous mudstone, carbonaceous shale and carbonaceous limestone and so on. Carbonaceous rocks are susceptible to weathering, low strength parameter index, water softening, softening, swelling, environmental sensitivity, disintegration and other engineering characteristics, belong to soft rock, produce significant plastic deformation and creep, it may cause the crack deformation of tunnel lining in the construction and operation of the carbonaceous rock tunnel.

Guangxi mountain range, because of the wide distribution of carbonaceous rock and the tunnel of highway construction planning, it is unavoidable to pass through carbonaceous rock, and the deformation of carbonaceous rock often has characteristics of accumulative expansion and time effect, which causes great difficulty to construction, and brings a series of problems to tunnel design and construction.
2. Engineering Overview
The project Airport tunnel entrance is located in Hechi City, Jincheng river District, Bagong town, the northwest side of the village about 150m. The exit port is located about 1 km southeast of the village of Maple Branch in Nandan County. During the tunnel excavation, the carbonaceous rock of the palm face is significantly influenced by the structure, rock occurs distortion, crumple phenomenon is obvious, the rock body can be seen smooth structure surface, local is clastic fragmentation structure, most of the surrounding rock is damp, there is groundwater. Since the carbonaceous rock has the characteristics of rapid weathering, hydrophilic strength and weak permeability, although the exposed rock surface is closed immediately after excavation, the carbonaceous rock in the excavated section is separated or collapsed because of its poor stability and the action of water.

3. Research Content
In view of the above issues, the pile number of the left-line carbonaceous rock section of the airport tunnel is Z2K4+055 ~ Z2K4+090 to bury the monitoring sensor, such as: multi-point displacement meter, earth pressure box, temperature and humidity sensor, automatic measuring instrument, osmotic pressure gauge, anchor rod stress gauge. Study the deformation mechanism and creep development law of the surrounding rock of the carbonaceous rock under the stress releasing state of the tunnel.

3.1. Monitoring Section placement
The carbonaceous rock section of the tunnel is determined according to the construction advance forecast and the state of the excavation, as Figure 1 shown in:

![Figure 1. Site monitoring plan for rock mass tunnel surrounding rocks](image)

In the carbonaceous rock tunnel, it was decorated a monitoring section every other 5m, and it total 5 section, each section in 0°left and right side, 45°left and right side, 90°, drilling 6 m-depth holes, embedding corresponding sensors.

3.2. Test implementation
The project group uses the DTH drilling rig to drill down the tunnel surrounding rock, after completing the drilling process, burying the sensor.
4. Based on Singh-Mitchell calculation and analysis of surrounding rock creep of model

4.1. Now collects nearly 100 days displacement monitoring data, osmotic pressure, temperature, as shown in Figure 2(a) ~ (c).

![Figure 2](a) Surrounding rock monitoring results chart

Figure 6 (a) shows that: The displacement is negative, indicating that the surrounding rock is pulled, and the displacement time history curve is the Power function type, the curve form is basically consistent. The displacement time history curve changes rapidly in the initial period, then the curve changes gradually slowly, the growth rate (slope) decreases and the curve finally stabilizes. Figure 6
(b) is osmotic pressure, it shows that except the 1 and 2 section, the others values are small, and in the Figure 6 (c) the temperature of 2, 3, 4 section are small.

Mechanism analysis: the factors that influence the deformation of surrounding rock include stress release caused by tunnel excavation, creep of rock caused by temperature, osmometer pressure of fissure, groundwater and rainfall, and construction factors, so the deformation regularity of surrounding rock should be composite analyzed.

4.2. The calculation and prediction of surrounding rock creep based on Singh-Mitchel model

In order to study the deformation regularity of surrounding rock of carbonaceous rock tunnel, predicting the creep and providing early warning information, the position of low osmotic pressure and temperature select to analyze the creep of surrounding rock.

The current rheological model divided into four categories: element model, yield surface model, internal time model and experiential model. The element model needs to introduce more components to simulate the viscoelastic-plastic characteristics of rock, the yield surface model and the internal-time model should have professional theory, and the experiential model is simple and practical. The advantages of classical exponential Singh-Mitchell experiential models are that the model parameters are few and easy to be determined, but the disadvantage is that the influencing factors are single. However, the model is a convenient and practical calculation method.

\[
d\varepsilon = A \cdot e^{\overline{D}(t)} \sum_{i=1}^{m} \left( \frac{m}{t} \right) dt
\]

Formula: \( \varepsilon \) is creep value, \( d\varepsilon \) is creep increment; \( A, \alpha, m \) calculate parameters for creep models; \( (t) \) is unit time, general fetch 1; \( \overline{D} = (\sigma_1 - \sigma_3) / (\sigma_1 - \sigma_3) \) is shear stress level; \( \frac{1}{2}(\sigma_1 - \sigma_3) = S_u \) is undrained shear strength, it can be obtained by reference related literatures.

Function 1 are integrated:

\[
\varepsilon = \varepsilon_0 + A \cdot e^{\overline{D}(t)} \sum_{i=1}^{m} \left( \frac{m}{t} \right) \]

Formula: \( \varepsilon_0 \) is the initial creep value.

Select the location (the 3 and 4 0°right side walls) of the small initial temperature and osmometer pressure of the surrounding rock, calculating the analyzing displacement by Singh-Mitchell model, the result is as follows Figure 3, the model parameters is as shown in tables 1:
Figure 3. The displacement calculation and test results of the surrounding rock based on Singh-Mitchell model

| Tables 1. The parameters of Singh-Mitchell model |
|-----------------------------------------------|
| Model parameters                               | (a)            | (b)            |
| \( \varepsilon_0 \)                            | 0.04389        | 0.48684        |
| \( A \cdot e^{\varepsilon T} \)                | -0.0136        | -0.23          |
| M                                              | 1.05           | 3.05           |

| \( R^2 \) Correlation coefficient              | 0.96796        | 0.89015        |

From the model parameter table, it concluded that the correlation coefficients of the calculated results by the Singh-Mitchell model are higher, and it could use only consider the stress level. Then the displacement of surrounding rock can calculate at any time through the obtained model parameters and the Singh-Mitchell model. The Figure 4 is displacement prediction of the surrounding rock before the operation of the carbonaceous tunnel.
Figure 4. Forecast 400 days surrounding rock displacement results map

Combine model parameters and the Singh-Mitchell model formulas to predict displacement of surrounding rock in 400 number days, the displacement values are: the 3 section 0° right side is -1.158mm, the 4 section 0° right side is -2.64mm. However, the temperature and osmotic pressure of the calculation position are small, only considering the stress level under the condition of static weight load.

5. Conclusion
The whole deformation of the surrounding rock in the carbonaceous rock tunnel during the excavation. Under the influence of construction and groundwater, the surrounding rock appears disintegration and mud phenomenon, which leads to lower stability of surrounding rock and reduced bearing capacity.

The results of the displacement of surrounding rock in the carbonaceous rock tunnel shows that the carbonaceous rock is a viscoelastic plastic material. The initial surrounding rock creep changes dramatically with time, the growth rate decreases, and the curve finally stabilizes.

Using Singh-Mitchell model to calculate and analyze the displacement of the surrounding rock of the carbonaceous rock tunnel, the correlation coefficient is higher. Model parameters obtained through the displacement monitoring of surrounding rock and Singh-Mitchell model in 100 days, then predict the displacement in 400 days. The law of creep development is important for guiding tunnel construction and taking measures to prevent and reinforce it.

Acknowledgments
Author Introduction: Junhui Luo(1985-), Male, Doctor of Engineering, graduated with his bachelor's degree from Central South University in urban underground space engineering, now is a researcher, mainly engaged in geotechnical engineering. E-mail:83569159@qq.com

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