Study on creep characteristics of residual soil in Central Yunnan Water Diversion Project

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Abstract: Sericite schist is an extremely soft rock. Most of the sericite schist residual soil in nature is in an unsaturated state, The matrix suction of the residual soil has a great influence on its strength. In this paper, an unsaturated quadruple consolidation tester and an unsaturated triaxial creep tester are used to carry out one-dimensional and three-axis creep tests on sericite schist residual soil. The test results show that the creep characteristics of the soil sample are obvious. Both the one-dimensional and triaxial tests show obvious three-stage characteristics. At the same time, the influence of the matrix suction and the net vertical stress on the creep characteristics of the soil is comparatively analyzed.

1. Introduction
The creep of soil is a process in which the deformation of soil increases with time under constant stress[1]. In practical engineering, the settlement of building foundation, the stability of slope, the deformation of tunnel construction, etc., the long-term mechanical behavior of these soils are closely related to creep[1-5]. With the influence of rainfall and groundwater, its unsaturated characteristics become more obvious, and the influence on its strength becomes more and more intense, which leads to its obvious rheological characteristics and increases its creep deformation. Its creep is related to volume deformation and particle creep. The creep problem is complex and has an obvious influence on its engineering performance. Therefore, it is necessary to study its unsaturated creep characteristics.

Wang Kai et al[6]. carried out triaxial creep test on landslide soil in Nanping tunnel. It was found that the creep characteristics of this kind of clay can be described by Xiuyan model. The long-term strength of soil was obtained by superposition principle and isochronal curve method. Creep parameters increased with the increase of confining pressure, and the decrease range of long-term strength compared with instantaneous strength also increased with the increase of confining pressure Lower. Jamel Kamoun et al[7]. carried out triaxial creep tests on disturbed soil samples with different saturation. The test results show that the initial saturation degree and the second invariant of the strain tensor have similar variation trend under the fixed stress level, whether it is isotropic stress path or non anisotropic stress path. The variation of axial creep strain is a semi logarithmic function with time. Bhat D R[8]. The results show that the creep failure begins only when the applied shear stress (i.e. creep stress) is greater than the residual strength, and there is no creep effect on or below the residual strength. The residual creep failure prediction curve is proposed, which provides a basis for the failure time prediction of creep landslide in the future.

In this paper, the sericite schist residual soil in the water diversion tunnel of central Yunnan water...
diversion project is taken as the research object, and the one-dimensional creep test and triaxial creep test under different matric suction are carried out to study its unsaturated creep characteristics, so as to provide theoretical guidance for the development of practical engineering.

2. Guinea-pig
The test material is taken from the sericite schist residual soil in Yulong County, dalijiang City, Yunnan Province. It is gray and belongs to the lower Paleozoic Lancang group sericite schist and sericite quartz schist intercalated with carbonaceous sericite schist belt. Affected by the structure and weathering, the rock is seriously broken and highly weathered, forming a large amount of residual soil. See Figure 1. According to the standard of soil test method (GB/t50123-1999), the basic physical properties of the soil are tested, and the experimental results are shown in Table 1.

![Fig. 1 Residual soil of sericite schist](image1)

Through scanning electron microscope and X-ray diffraction, it is found that the unsaturated sericite schist residual soil is mainly composed of lamellar meta crystalline quartz, muscovite and a few dolomite, kaolinite and chlorite with particle size \( \leq 0.6 \) mm.

3. One-dimensional creep deformation characteristics

3.1. Testing program
In order to study the one-dimensional creep deformation mechanism of Sericite schist residual soil, the fgi-20 unsaturated quadruple consolidation apparatus was used to carry out the creep test of controlling matrix suction, and the creep characteristics of unsaturated sericite schist residual soil under different matrix suction were discussed.

The soil sample is crushed through a 2mm sieve, dried and prepared into a soil sample with a diameter of 61.8mm and a height of 20mm according to the ratio of 10% moisture content. In the test, the matric suction was controlled to be 0, 50, 100 and 200kPa respectively, and the net vertical stress of 50, 100, 200 and 300 kPa was applied to carry out one-dimensional creep test.
3.2. Experimental results and analysis
Through unsaturated one-dimensional creep test, the relationship between axial displacement change and time is obtained, as shown in Figure 3. It can be seen from Fig. 3 that the sample will undergo instantaneous elastic deformation under each level of shear stress, and the creep deformation increases with the increase of shear stress. The change curve can be divided into three stages: the first stage is the rapid growth stage, in which the instantaneous elastic deformation occurs; the second stage is the slow growth stage, in which the creep deformation continues to increase, but the growth rate is slower than the first stage; the third stage is the stable stage, in which the creep deformation tends to be stable with the increase of time. With the increase of shear stress, the creep deformation increases greatly, but it takes longer to reach the deformation stability. It can be seen from the curve that the instantaneous elastic deformation and creep displacement of the sample decrease with the increase of the matrix suction, which reflects the creep characteristics of Sericite schist residual soil.

![Figure 3: One dimensional creep test curve](image)

4. Creep model
According to the one-dimensional creep curve, when the matrix suction is the same, the strain increases with the increase of vertical stress. Creep characteristics show that when the stress level is low, it starts to deform rapidly, and gradually becomes stable creep after a period of time. When the stress level exceeds the critical stress value of sericite residual soil, it gradually turns into unstable creep, which accords with the description of Xiyuan model. In order to further study the creep characteristics of sericite schist residual soil, Xiyuan model (Figure 4) is adopted as the rheological model of the residual soil.
The creep equation of Xiyuan model is as follows

When $\sigma_0 < \sigma_s$

$$\varepsilon = \frac{\sigma_0}{E_1} + \frac{\sigma_s}{E_2} \left( 1 - e^{-\frac{E_2 t}{\eta_1}} \right)$$

(1)

When $\sigma_0 \geq \sigma_s$

$$\varepsilon = \frac{\sigma_0}{E_2} \left( 1 - e^{-\frac{E_2 t}{\eta_1}} \right) + \frac{\sigma_s - \sigma_0}{\eta_2}$$

(2)

Where: $E_1$ is the elastic modulus, $E_2$ is the viscoelastic modulus, $\eta_1$ is the viscoelastic coefficient (Pa·s) corresponding to the transitional creep stage $\eta_2$ is the viscoelastic coefficient (Pa·s) corresponding to the creep stage at constant strain rate $\sigma_s$ is the yield stress.

In order to obtain the rheological parameters in line with the actual situation, the optimized inversion method of step-by-step iteration is adopted.

When $\sigma_0 < \sigma_s$ The generalized Kelvin model consists of three rheological parameters: instantaneous elastic modulus $E_1$, viscoelastic modulus $E_2$ and viscosity coefficient $\eta_1$. The formula of $E_1$ and $E_2$ is

$$E_1 = \frac{\sigma}{\varepsilon_0}$$

(3)

$$E_2 = \frac{\sigma}{\varepsilon_\infty - \varepsilon_0}$$

(4)

Where: $\varepsilon_0$ is the strain at $t=0$; $\varepsilon_\infty$ is the stable strain when $t$ tends to $\infty$.

$\sigma_0 < \sigma_s$ $E_1$ and $E_2$ obtained from equations (3) and (4), where $\varepsilon_0$ and $\varepsilon_\infty$ can be obtained directly from the test curve.

Suppose that the rheological parameter $X = (X_1) = (\eta_1)$ As design variables.

By substituting the design variables of rheological parameters into equation (1), $t$ at each stress level is calculated. The axial strain value at $\varepsilon_i(X, t_i)$.

The objective function of rheological parameter inversion is established

$$F(X) = \sum_{i=1}^{n} (\varepsilon_i(X, t_i) - \varepsilon_i)^2$$

According to the optimized inversion method of rheological parameters mentioned above, the rheological inversion curve of sericite schist residual soil can be obtained by inversion.

It can be seen from Figure 5 that the calculated results of creep model are in good agreement with the creep test results, indicating that the identified Xiyuan model can better reflect the creep characteristics of sericite schist residual soil.
5. Conclusion
(1) One-dimensional creep test of unsaturated sericite schist residual soil has obvious three-stage characteristics. The creep characteristics of the soil sample are obvious, and the test is stepped with the application of each grade of shear stress.

(2) Three stages of one-dimensional creep test: the first stage is the rapid growth stage, and the sample undergoes instantaneous elastic deformation; The second stage is a slow growth stage, and the growth rate is slower than the first stage; The third stage is the stable stage, and the creep deformation gradually tends to be stable with the increase of time. It can also be seen from the curve that the instantaneous elastic deformation and creep displacement of the sample decrease with the increase of matrix suction, which reflects the creep characteristics of sericite schist residual soil.

(3) The three stages of unsaturated one-dimensional creep experimental curve are initial creep stage, stable creep stage and accelerated creep stage. When the matric suction is the same, the creep displacement increases with the increase of net vertical stress until the specimen fails. It shows that matrix suction plays a great role in the whole creep process.

(4) The ability of soil to resist deformation increases with the increase of matric suction. Therefore, in practical engineering, the change of matric suction will affect the instantaneous elastic deformation and long-term creep deformation of water conveyance tunnel, which will lead to the settlement and.

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