Strength characteristics test of expansive soil with interlayer and slope stability analysis

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ABSTRACT

The existence of fissures in expansive soil directly destroys the integrity of the soil, reduces the strength, and leads to the decrease of the stability of the slope. The landslide often occurs after the excavation. The expansive soil area of the main channel of the Middle Route of the South-to-North Water Transfer Project in China is about 270 kilometers, accounting for 27% of the total length of the whole line. The instability of the expansive soil slope will seriously affect the construction and normal water delivery. Therefore, Studying the strength characteristics of the expansive soil interlayer and the stability analysis method is of great significance for ensuring the safe operation of the Middle Route of the South-to-North Water Transfer Project.

Interlayer is one of the three characteristics of expansive soil, and it is also the most intuitive and obvious feature in expansive soil engineering. The weak interlayer make the strength characteristics of expansive soil complex. The strength of expansive soil can be divided into soil matrix strength, interlayer strength and soil strength. The strength of the soil is controlled by the distribution, density, inclination, inclination, extension range, filling condition and properties of the soil matrix, and the orientation of the interlayer causes the anisotropy of soil shear strength.

Based on the triaxial test sample preparation method, by modifying the mold, a strong expansive soil interlayer is placed into the sample, and the thickness and inclination of the interlayer are controllable. A interlayer sample preparation device and method based on layered filling-bevel cutting-refilling are proposed. The sample preparation device comprises a base and a mold fixing module, a sample pushing and positioning module, and a sample mold set. The device adopts a modular design, and the intermediate block is replaced to realize the control of the inclination of the interlayer, which is simple and easy to operate (see Fig. 1).

Interlayer samples with inclination of 15°, 30°, 45° and thickness of 7 mm were prepared, and a interlayerless triaxial sample was prepared by the medium expansive soil for comparative test. Figure 2 shows the typical failure mode of the triaxial samples without a interlayer, with a 15° dip interlayer, a 30° dip interlayer, and a 45° dip interlayer.

![Schematic diagram of the test device](image1)

![Triaxial sample failure modes and the failure surface](image2)

The peak stress ($\sigma_{1f}$-$\sigma_{3f}$) at the time of sample failure was obtained from the stress-strain relationship curve of the triaxial test results. According to the static equilibrium condition, the normal stress $\sigma_n$ and the shear stress $\tau$ on the interlayer are calculated by using the equation (1) and the equation (2).

$$\sigma_n = \frac{(\sigma_{1f} + \sigma_{3f}) + (\sigma_{1f} - \sigma_{3f}) \cos 2\alpha}{2}$$

$$\tau = \frac{(\sigma_{1f} - \sigma_{3f})}{2 \sin 2\alpha}$$

Where: $\sigma_{1f}$ is the peak principal stress, $\sigma_{3f}$ is the peak small principal stress, $\alpha$ is the angle between the shear failure surface and the horizontal plane.

After the gray-white strong expansive soil interlayer is placed in the medium expansive soil, the interlayer has a
great influence on the mechanical properties of the expansive soil, resulting in different degrees of intensity attenuation in each load grade of the triaxial test, and the intensity of the attenuation is positively correlated with the inclination. The shear strength parameters of the interlayer are basically stable, the cohesion $c$ is about 12-15 kPa, and the internal friction angle $\phi$ is about 3-5°. In terms of deformation characteristics, after the interlayer is added, the deformation characteristics of the sample develop from strain hardening to strain softening, and the strain softening is most remarkable when the interlayer is 45°. (see Fig. 3)

On the basis of a large number of on-site landslide investigations, the spatial distribution information and geometrical shape of typical controlled fissures were put in the model, and the strength parameters of the fissure surface interlayer were considered. The geological model of the fractured slope of the expansive soil was established (see Fig. 4). Taking the typical landslide of the Middle Route of the South-to-North Water Transfer Project as a stability analysis example, the stability of the slope with expansive soil was analyzed. The results show that, the presence of weak interlayer has a significant effect on the weakening of soil strength. The higher the coincidence of the slope geological model with the real slope, the closer its stability is. When considering the vertical fissures, groundwater and gentle-dipping fissure at toe of the slope, safety factors reduce significantly, sliding surface which made of vertical fissure at slope top and slip surface developed from the bottom of the vertical fissures to the slope foot, assume a broken line form, and the sliding surface type is basically consistent with the typical landslide damage characteristics in engineering practice (see Fig. 5).

**Keywords:** expansive soil, interlayer, strength, slope stability

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