Study on soil-water characteristics of unsaturated sericite schist residual soils

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Abstract. The residual soil of Sericite schist softens and becomes loose when encountering water, which is easy to be damaged by wetting. Its engineering properties are obviously affected by water, so it is necessary to study its soil water characteristics. In this paper, the matric suction of Sericite schist residual soil under different dry density is measured by filter paper method. It is found that the change of soil water characteristic curve of Sericite climbing residual soil is not typical “s”, and there is no obvious unsaturated residual section. The main reason is that the residual soil of Sericite schist has sheet structure, easy drainage channel and fast water loss speed, the change of matrix suction is large. Because of its lamellar structure, its water holding capacity is poor, so the unsaturated residual section of its soil water characteristic curve has no obvious change.

1. Research background

In recent years, with the development of engineering technology and new industrial requirements, the utilization of soft rock and residual soil has gradually attracted attention from home and abroad. The local utilization of soft rock and residual soil can not only reduce the engineering cost, but also solve the problem of lack of engineering materials and meet the requirements of ecological environment protection.

The study of soil water characteristics of unsaturated soil has always been the focus of unsaturated soil mechanics. The existence of matric suction makes the properties of unsaturated soil different from those of saturated soil. Matric suction in soil reflects the law of soil moisture migration in unsaturated state. It plays an important role in the study of engineering properties of unsaturated soil[1]. The relationship between matric suction and water content can be used in soil water characteristics Curve) is an important way to understand the water holding characteristics of unsaturated soil and other performance indicators (such as strength, unsaturated permeability coefficient, etc.)[2]. Arezoo Rahimi et al[7] proposed a new method to estimate SWCC data points with suction over 100 kPa, and conducted extensive SWCC tests on coarse kaolin. It was found that this method can reduce the change of unsaturated permeability function estimated by various estimation models. Qin shanglin et al[8] carried out tests under different stress paths on sericite schist with triaxial testing machine, and observed its acoustic emission signals. The research shows that the activities between particles are greatly affected by confining pressure and stress level, so the acoustic emission signals are different at different stages.
At present, the research on the residual soil of Sericite schist mainly focuses on its deformation and properties in saturated state, while the research on the strength and deformation of the residual soil by using the mechanical test method of unsaturated soil is rarely reported. Therefore, it is necessary to study the water characteristics of Sericite schist residual soil in unsaturated soil.

2. Test soil sample and physical and mechanical parameters

The test material is from the residual soil of Sericite schist of Dalin railway in Yunnan Province, which is gray, as shown in Figure 1. Affected by the structure and weathering, the rock is seriously broken and highly weathered, forming a large number of residual soil. Through X-ray diffraction analysis, it is found that it is mainly composed of granular quartz, muscovite and a few dolomite, kaolinite and chlorite with particle size ≤ 0.6mm. By scanning electron microscopy, The schistose variable crystalline muscovite and chlorite are arranged in a discontinuous continuous direction to form a schistose structure. Other grain minerals are unevenly distributed among quartz grains, as shown in Figure 2. According to the standard for soil test methods (GB/T50123-1999) [9], the basic physical properties of the soil are tested, and the test results are shown in Table 1.

![Figure 1. Residual soil of Sericite schist.](image1)

![Figure 2. SEM image of Sericite schist residual soil.](image2)

| Specific gravity /Gs | Liquid limit /% | Plastic limit /% | Maximum dry density /g.cm\(^3\) | Optimum moisture content /% |
|---------------------|----------------|----------------|-------------------------------|-----------------------------|
| 2.76                | 20.35          | 8.15           | 2.10                          | 10                          |

3. Experimental Methods

3.1. Experimental Procedure

In this paper, the matric suction of Sericite schist residual soil is measured by filter paper method. Put the soil sample through 2 mm sieve and put it into the oven for drying. Take the dried soil and prepare the soil sample with moisture content of 5%, 6%, 8%, 10%, 12%, 14%, 16% and 18%, and keep it sealed for 24 hours. Prepare soil samples with dry density of 1.9g/cm\(^3\) and 2.10g/cm\(^3\), then weigh a certain amount of soil sample, put it into compaction mold, and compact it once. Two soil samples are connected and put into the sealed tank, three pieces of filter paper are placed between the two soil samples. Two pieces of protective filter paper are placed at the top and bottom, and the test filter paper is placed in the middle. A bracket is placed above the soil sample, and two pieces of filter paper are
placed on it to test the total suction. The cover of the sealed tank is covered and put into the incubator. The temperature of the incubator is set to 25 ℃. After 14 days, take out the soil sample, weigh the quality of the test filter paper, put the test filter paper into the oven for 24 hours, and then weigh the quality. At the same time, test the moisture content of the soil sample. At the same time, 32 groups of soil samples were set up in the control group, and the test lasted for 1 month.

3.2. Test results and analysis
In this paper, the matric suction test of Sericite schist residual soil is carried out with the domestic "double circle" brand standard filter paper (the saturated water content of the filter paper is about 200%), and the calibration equation of the filter paper curve of Bai Fuqing et al[10] is adopted, wherein formula (1) is the calibration formula of the total suction, formula (2) is the calibration formula of the matric suction, and the fitting result is shown in Figure 4.

\[
\begin{align*}
\lg(h_t) &= -0.070 w_{fp} + 5.257, \quad w_{fp} \leq 41\% \\
\lg(h_t) &= -1.194 w_{fp} + 51.321, \quad w_{fp} > 41\% \\
\lg(h_m) &= -0.076 w_{fp} + 5.493, \quad w_{fp} \leq 47\% \\
\lg(h_m) &= -0.012 w_{fp} + 2.470, \quad w_{fp} > 47\%
\end{align*}
\]

In the formula, \( h_t \) is the total suction, \( h_m \) is the matrix suction, \( w_{fp} \) is the moisture content of filter paper.

Figure 3 shows the soil-water characteristic curve of unsaturated sericite schist residual soil under different dry density. The soil water characteristic curve is not typical "s", but the transition section is more steep than other typical soil water characteristic curves, because most of the internal structure is flaky, once the air intake value is reached, the internal water and gas migration channel will be formed more quickly, and the water and gas migration speed will be faster. It is found that the change trend of soil water characteristic curve is that the matrix suction decreases with the increase of water content. When the water content of Sericite schist residual soil is low (i.e. CD section), it can be seen that the change of matrix suction of the two curves is basically the same, indicating that the dry density has little influence on it at this stage, but when the water content begins to increase gradually, the matrix suction of the samples with different dry density is big and small. The size of the matrix suction increases with the increase of water content, and the suction of the substrate with larger dry density
is greater than the suction of the substrate with smaller dry density, mainly because the larger the dry density, the smaller the pore ratio of the soil and the saturation, the water content at that time is also smaller.

According to the water content, the soil water characteristic curve can be divided into three sections. The water content of the soil in section AB is high, and the pores in the soil are full of water. At this stage, the soil is completely closed in the gas phase, and the matric suction changes obviously with the water content. Starting from point B, the change range of matrix suction with water content is smaller than that of section ab. This stage is the process of soil changing from water closed state to gas closed state. At the initial stage of transformation, the soil is in the water closed structure. After point B, with the gas entering, the change range of water content increases, the pore water and gas are not continuous, the soil is in the double closed state, and point B is its air inlet point. At this time, the gas phase in the soil is completely connected, and the slight change of water content in the soil will cause a significant increase of matrix suction. At this time, point C is its residual water content.

The soil water characteristic curve model is used to further analyze the test results and fit the actual measured water content and matrix suction data. Gardner (1958) [11] model is a three parameter model, the fitted soil water characteristic curve presents "s" type in semi logarithmic coordinate, van Genuchten (1980) [12] is a four parameter model, the relationship between matrix suction and water content is expressed in the form of power function, and the mathematical expression is divided into formula (3) and formula (4). The fitting curve is shown in Figure 4, and the fitting results are shown in Table 2. Both models have better fitting effect, but the VG model with four parameters has higher fitting accuracy.

\[
\begin{align*}
\theta &= \theta_r + \frac{\theta_s - \theta_r}{1 + (s/\alpha)^{n}} \quad (3) \\
\theta &= \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha s)^{n}]} \quad (4)
\end{align*}
\]

In the formula, \( \theta \) - volume water content, \( \theta_r \) - residual water content, s - matrix suction, \( \theta_s \) - saturated water content, \( \alpha, q, n \) - test fitting parameters.

| Model               | \( \rho_d=1.95 \text{g/cm}^3 \) | Correlation coefficient | RMSE | \( \rho_d=2.10 \text{g/cm}^3 \) | Correlation coefficient | RMSE |
|---------------------|---------------------------------|-------------------------|------|---------------------------------|-------------------------|------|
| Gardner model       | 0.975                           | 0.022                   | 0.975| 0.012                           |
| Van Genuchten model | 0.986                           | 0.011                   | 0.980| 0.011                           |

4. Conclusion

In this chapter, aiming at the residual soil of Sericite schist in the test section, the soil water characteristics of the residual soil of Sericite schist are tested by the method of filter paper, and the soil water characteristics of the residual soil of Sericite schist with different dry density are studied by the VG and Gd models. Through the above research, we can get the following conclusions:

(1) The soil water characteristic curve of Sericite schist residual soil is not a typical "s" curve, and its transition section is more steep than other typical soil water characteristic curves. As the internal structure of Sericite schist residual soil is layered, once the air intake value is reached, the internal water and gas migration channel is formed rapidly, the water and gas migration speed is faster, and the matrix suction in the soil decreases rapidly with the increase of water content.

(2) The matric suction varies with the dry density. The matric suction of soil with large dry density is larger than that of soil with small dry density. The main reason is that the higher the dry density is, the denser the soil structure is, the less the internal pore channels are, and the corresponding matrix
suction increases. However, with the decrease of water content, the change trend gradually decreased, and the matric suction began to approach.

(3) Based on Gardner model and van genucht model, the original software is used to fit the two kinds of silty sand. From the perspective of correlation coefficient and error, the fitting results of the two models are good. Because van genucht model has many parameters and is more complex, the Gardner model can be used to fit the soil similar to the plateau Huxiang silty soil.

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