Experimental study on soil water characteristic curve of unsaturated loess in Xining area

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Abstract. The soil water characteristic curve is an important hydraulic characteristic parameter of unsaturated soil, and plays an important role in the analysis of unsaturated soil strength and slope stability. At present, there are few studies on soil water characteristics in Xining area. In this paper, the matrix suction value of undisturbed loess in Xining area is tested by filter paper method under different water content, then the soil water characteristic curve is obtained. The specific analysis of the test results shows that the soil sample at the same depth increases the matrix suction during the dehydration process, and the volumetric water content of the soil sample decreases gradually. This paper lays a foundation for the study of the impact of rainfall infiltration on the shear strength of slope soil and the stability impact.

1. Introduction

The soil water characteristic curve (SWCC) is a relationship between the matric suction of unsaturated soil and the soil saturation or volumetric water content [1-2], the shear strength and penetration of unsaturated soils. Regularity and deformation characteristics are closely related to it. Unsaturated soil is widely distributed in arid and semi-arid regions and is above the groundwater level. Suction is one of the most important parameters determining the characteristics of unsaturated soils, and one of the most difficult parameters for unsaturated soils [3]. The SWCC curve has been relatively mature for predicting the shear strength of unsaturated soils. The SWCC curve is also the basis for the study of unsaturated soils. The commonly used means to obtain the characteristic curve of soil water is divided into direct method and indirect method. The direct method includes a pressure plate meter, a pressure membrane meter, a rapid centrifugation method, an indirect method with a dialysis method, and a filter paper method. Among these measurement methods, the filter paper test has the advantages of simple, safe and low cost, and can measure the total matrix suction range of the soil, and the soil is not widely damaged and has been widely used. Wang Hao [4], Shen Zhenyao [5], Jiang Gang [6] introduced the device and measurement results of the substrate suction measurement by the filter paper method, and compared with the results of the tension meter measurement and the water and soil characteristic curve, indicating that the developed device is simple and practical. The paper [4] also introduces the calibration process and calibration curve of double-circle filter paper, and discusses some factors that affect the measurement accuracy. Therefore, in order to study the soil-water characteristics of loess in Xining, we use the filter paper method to test the soil water characteristic curve.

2. Soil water characteristic curve by filter paper method

2.1. Selection of soil samples and basic physical indicators
The test soil samples were collected from loess in a certain area of Qinghai University in Xining City. The sampling work was carried out by means of artificial excavation and exploration. The wellhead was 60 cm × 60 cm and the depth was 6 m, 10 pieces of rectangular clods of 20 cm × 20 cm × 20 cm were cut every 1 m in the vertical direction of the well wall to avoid disturbance. Immediately after sampling, they were wrapped and sealed and placed in a cardboard box with a shock-proof foam layer and transported back to the laboratory. The results of testing the physical indexes of soil samples in accordance with the Standards for Geotechnical Test Methods are shown in Table 1.

| Moisture content/ % | Liquid limit/ % | Plastic limit/ % | Dry density (g/cm³) | Optimum moisture content/ % | Maximum dry density (g/cm³) | Soil specific gravity/Gs |
|---------------------|-----------------|------------------|---------------------|-----------------------------|----------------------------|-------------------------|
| 10.2                | 25.             | 15.3             | 1.411               | 15.5                        | 1.92                       | 2.7                     |

### 2.2. Sample preparation and test method

#### 2.2.1. Sample preparation

The ring knife sample was prepared. The ring cutter model is 2 cm high and 6.18 cm in diameter. The sample is saturated by the capillary saturation method, which usually takes about 3 days.

#### 2.2.2. Filter paper method for suction test steps

The suction was measured by the “double circle” brand No. 203 filter paper of Hangzhou Xinhua Paper Mill, accounting for 0.01% by mass, and the filtration rate was slow. The protective filter paper and the test filter paper are 60 mm and 50 mm in diameter, respectively. Follow the steps below for the measurement: The first, weigh the double-circle No. 203 filter paper that has been baked in a 105 °C, oven to the nearest 0.0001 g. The second, take the soil sample of the processed ring knife, and lay the center of the ring cutter φ=60mm, φ= 50mm, φ= 60mm in turn, then place a ring of soil sample with the same water content on the filter paper, press the two ring cutter and use The cling film wraps it tightly, possibly expelling the air, and the tape seals and labels it. The third, put the wrapped soil into a sealed box that has been heat treated for 1 d, and then place it in a constant temperature oven at 26 °C for one week to achieve suction balance. Then, use a clean tweezers to clamp the intermediate layer φ= 50mm filter paper that has completed the pore water balance. In order to reduce the water and gas exchange between the filter paper and the surrounding air, the weighing of the filter paper should be rapid. The weighing should be completed within 30 seconds. The reading should be accurate to 0.0001. The weighing has been dried in a 105 °C oven to the weight of the wet filter paper. The water content of the filter paper before and after drying. The last, substituting the measured data into the matrix suction force of the double-loop No. 203 filter paper matrix suction rate determining curve determined by Wang Zhao.

\[
\log h_m = \frac{-0.0120 \omega_{fp} + 2.470, \omega_{fp} > 47\%}{5.493, \omega_{fp} \leq 47\%}
\]

Where: \(h_m\) is suction, kPa; \(\omega_{fp}\) is water content of filter paper, %.

### 3. Experimental results and analysis

#### 3.1. Data Analysis

The initial water content of the soil sample has a considerable influence on the structure of the fine-grained soil, which in turn affects its swcc. In this experiment, soil samples with different initial moisture contents were selected and three sets of tests were carried out. Figure 1 shows the soil-water
characteristic curves corresponding to different initial water contents under zero vertical pressure. It can be seen from the figure: (1) At high water content, the soil-water characteristic curves of different initial water contents have coincident points, and there is no significant difference. (2) The volumetric water content is inversely proportional to the matrix suction, that is, as the volumetric water content of the soil decreases, the matrix suction increases. (3) With the change of initial water content, the slope of the curve does not change much, the initial water content has little effect on the water holding capacity of the soil.

4. Summary
In this paper, the soil-water characteristic curve of unsaturated loess in Xining was tested by filter paper method. And we can get the following conclusions.
(1) Filter paper method is simple, practical and low-cost in testing the matrix suction of unsaturated loess. However, the operation process is strict with the environment, if the test filter paper is in poor contact with the soil sample, the result of the matrix suction may be too large.
(2) In the future work, the soil water characteristic curve of loess in Xining area will be fitted to the formula, and it will be compared to the work results of the predecessors.

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