*Journal of Computing and Electronic Information Management*

ISSN: 2413-1660

# Experimental studies on materials for loess improvement: a review

Xiao Xie [1,2,3,4,5, *], Yulu Wei [1,2,3,4,5]

[1] Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China;

[2] Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, Shaanxi;

[3] Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources, Xi'an 710075, China;

[4] Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710075, China;

[5] Land Engineering Technology Innovation Center, Ministry of Natural Resource, Xi'an 710075, China

**Abstract:** Soil permeability is one of the important characteristics of soil, and it is a key parameter in the research and engineering design of irrigation, drainage, geotechnical engineering, hydraulic engineering, soil and water conservation in agricultural engineering. The principle of saturated soil permeability coefficient determination, several commonly used determination and calculation methods of saturated permeability coefficient, including in-situ measurement method and indoor measurement method were introducted in this paper. At the same time, the advantages and disadvantages of each method were analyzed and compared, in order to provide the basis for the accurate measurement of permeability coefficient in related research and engineering application.

**Keywords:** Saturated permeability coefficient, double ring method, triaxial permeability test, conventional permeability test.

## 1. Introduction

The phenomenon of water flowing in soil pores under pressure difference is called water seepage. The nature of soil permeability is called soil permeability. The saturated permeability coefficient of soil describes the permeability of soil under fully saturated state. For agriculture and forestry, soil infiltration is an important part of soil moisture cycle [1]. The source, migration and storage of water in plants are closely related to water infiltration, so the permeability of soil is closely related to the growth of plants and the effect of soil and water conservation [2] . For the construction of the project, the permeability of the soil layer affects the water environment in the study area, reflects the ability of the soil layer to transmit water and is the basic hydrogeological parameter that needs to be paid attention to. In geotechnical engineering, soil permeability, deformation and strength are the main research contents of soil mechanics. The permeability of soil has a significant impact on the deformation and strength of soil [3] . The study of soil permeability can provide necessary data for the design and construction of foundation, subgrade, slope stability evaluation and support design.

## 2. Principle of permeability coefficient measurement

The permeability of soil is expressed by the seepage rate under the action of a unit hydraulic gradient. Because the pore structure of soil is complex and the pores of the soil are generally very small, the viscous resistance of water passing through the soil is large, and the flow velocity is slow. Therefore, its flow state is mostly laminar flow, and its movement process conforms to Darcy's law [4], as shown in Formula (1).

$$v = k\frac{h}{L} = ki \tag{1}$$

Or

$$q = vA = kiA \tag{2}$$

In this formula, v is the infiltration rate of the soil, cm/s or m/s; q is the seepage flow through the soil, $cm^3/s$ or $m^3/s$, and i is the hydraulic slope, which represents the head loss per unit length along the flow direction; h represents the head difference of the calculated soil thickness range, cm or m, $h=h_1-h_2$, $h_1$ and $h_2$ are the heads at both ends of the soil sample calculation respectively; L is the seepage diameter length, cm or m; k represents the permeability coefficient or water conduction The rate, cm/s or m/s, is a soil constant, representing the permeation rate per unit hydraulic gradient.

In the experiment of measuring soil permeability coefficient, it is assumed that the seepage flow in the soil conforms to Darcy's law, and then the calculation is carried out based on the experimental data. Currently, there are field (in-situ) experiments and indoor experiments to determine the soil permeability coefficient.

## 3. In-situ measurement of saturated permeability coefficient

There are water injection experiments and pumping experiments to determine the permeability coefficient in situ. Generally, drilling or digging test pits on site, injecting or pumping water into them, measuring the head difference and seepage flow, and then calculating the permeability coefficient according to the formula. Water injection experiments mainly include single-loop method, double-loop method and trial pit method. The accuracy of the double-loop method is relatively high, and the measurement of the double-loop method is mainly introduced here.

Find a relatively flat place at the place where the permeability coefficient needs to be measured, and insert two iron rings (H=50 cm, d=20cm/40cm) into the position to be measured. During the test, water is injected into the inner and outer iron rings at the same time to ensure that the water surface of the inner and outer rings is at the same height, and the amount of water infiltration is recorded at a certain time interval. The observation time interval can be adjusted according to the rate of water infiltration. When the double-ring method is used for measurement, the outer ring restricts the inner ring, so the inner ring only produces vertical water infiltration. Compared with the single-ring method, there is no lateral seepage error, so the accuracy is higher.

When the infiltration water volume tends to be stable, the soil permeability coefficient can be obtained by calculating according to formula (3).

$$k=\frac{QL}{A(\mathrm{H}+Z+L)} \tag{3}$$

Where Q is the amount of water infiltrated per minute when the seepage is stable; L is the depth of water infiltration (cm) after the measurement is completed, which can be determined by excavation after the measurement is completed; A is the seepage cross-sectional area, that is, the cross-sectional area of the inner ring ($cm^2$), H is the capillary pressure of the soil, generally 1/2 of the capillary rise height (cm), and Z is the height of the water surface in the inner ring (cm).

## 4. Laboratory measurement of saturated permeability coefficient

The field test of the permeability coefficient is carried out in situ, which is more in line with the actual conditions of the soil sample. However, the field in-situ test is more affected by environmental conditions and test operations, so the test results fluctuate greatly [5]. The indoor experimental sample is small, easy to obtain, and the experimental device and operation requirements are simple. However, loose samples such as sandy soil are difficult to obtain the original samples, and the in-situ conditions of the samples are different.

The indoor test methods of soil saturated permeability coefficient include conventional permeability test, triaxial permeability test, ring knife method and soil column compression method. This article mainly introduces the commonly used test instruments for conventional infiltration experiments-the 55-type infiltration meter and the stress-strain controlled triaxial shear infiltration meter produced by Nanjing Soil Instrument Factory.

## 4.1 Conventional permeability test

There are two kinds of conventional permeability tests: varying-head and constant-head test. Constant head test is to keep the head ( head difference ) consistent in the test process, which is suitable for sandy soil with faster seepage velocity. Varying head test refers to the change of head ( head difference ) with time during the experiment, which is suitable for clay and silty soil with slow permeability. When using this method to carry out the experiment, the requirements for the experimental samples are high, and there is no gap between the soil sample and the ring knife. In addition, when the soil sample is taken, the surface of the ring knife sample cannot be repeatedly smeared with cutter, so as to avoid affecting the original porosity of the soil sample.

The constant head infiltration test is based on the principle of Mahalanobis bottle to keep the head in a constant height during the experiment, and the seepage flow in a certain time is calculated. The specific measurement process of variable head infiltration method is shown in Reference [6].

## 4.2 Triaxial permeability test

Triaxial permeability test instrument adopts the stress-strain controlled triaxial shear permeability instrument produced by Nanjing Soil Instrument Factory. Triaxial permeability test is to set a certain confining pressure after the soil sample is saturated and consolidated, so that the soil sample can be penetrated under a certain water head difference.

The sample sizes of triaxial permeability test are generally Φ6.18 cm*12 cm and Φ3.91 cm*8 cm, and the original samples can be taken in the field or the remolded samples can be prepared in the laboratory according to the experimental requirements. Soil samples need to be saturated before infiltration experiments. There are two ways to saturated soil samples : one is to use vacuum before sample loading, the other is to use back pressure after sample loading. The specific experimental steps are shown in Reference [7]. When setting the test parameters, it should be noted that the confining pressure should be slightly larger than the difference between the back pressure 1 and the back pressure 2 to prevent seepage from the soil sample and the rubber film. The permeability coefficient can be calculated after the seepage of the upper and lower parts of the soil sample is stable.

The permeability coefficient is calculated by taking the data of a certain period after the seepage is stable, and the calculation formula is shown in Equation (4).

$$k=\frac{\Delta Q\times H}{10.2\times\Delta P\times A\times\Delta \mathrm{t}} \tag{4}$$

In this formula, △Q is the seepage variation in the selected calculation time. In the triaxial test, the seepage flows from the bottom of the sample and from the top of the sample by means of the back pressure, so $\triangle Q$ is the average value (mL) of the upper and lower stable flow. H is the diameter, here is the soil height (cm). $\triangle P$ is the pressure difference between back pressure 1 and back pressure 2 (kPa), $10.2\times\triangle P$ is the pressure head (cm). A is the cross-sectional area of the sample ($cm^3$), $\triangle t$ is the seepage calculation time.

4.3 Comparative analysis of conventional penetration test and triaxial penetration test

The soil specimens for conventional infiltration experiments are easy to obtain, and the experiment operation is simple. However, there is a gap between the soil sample and the ring cutter. During the experiment, water will leak from the gap between the ring cutter and the soil sample. The permeability coefficient usually measured is generally too large. At the same time, compared with the triaxial test, the conventional infiltration test cannot control the confining pressure during infiltration, and there will be stress release when the soil sample is taken out from the original position, which makes the test results differ from the actual test results.

The advantage of the triaxial permeability test is that the confining pressure can be set according to the actual situation and test requirements, which can be more in line with the in-situ condition of the soil sample; the triaxial permeability test can apply back pressure to the soil sample and saturate the soil sample through back pressure to avoid Some soft soils are structurally damaged when they are saturated by vacuum; the triaxial test can also avoid water seepage between the sample and the rubber membrane by setting the confining pressure, which will affect the penetration test results. The disadvantage is that the soil specimen (especially the soil with high viscosity) takes a long time to saturate on the triaxial instrument.

## 5. Conclusion and suggestion

The soil permeability coefficient is affected by many factors such as experimental conditions, experimental methods, soil sample quality, and experimental operations. Field experiments are more in line with the in-situ conditions of soil specimens, but are greatly affected by environmental conditions. Specimens of indoor experiment are small and easy to obtain, the experimental equipment and operation requirements are simple, but have certain disparity with the in-situ conditions. Among them, the triaxial penetration experiment is more in line with In-situ conditions of soil specimens. To accurately determine the permeability coefficient, attention should be paid to the airtightness of the apparatus components during the on-site measurement, and parallel tests should be carried out. When conducting indoor tests, the quality of the collected soil specimens should be ensured, and the liquid level readings should be read manually. At the same time, it is recommended that two researchers read separately to reduce human-made reading errors. At the same time, the instrument operation process should be standardized, the experimental parameter setting should be paid attention to, and the experimental apparatus should be adjusted according to the test requirements to improve the accuracy of the permeability coefficient measurement.

## References

[1] Wei Lingna,Chen Xi,Cheng Qinbo,et al. Analysis of Soil Permeability and Its Influence by Vegetation in Red Soil Hilly Region [J]. China Science and Technology Papers, 2013, 8(5):377-380.

[2] Chen Huizhe, Zhu Defeng, Lin Xianqing, et al. Effects of Soil Water Permeability on Rice Root Growth and Nitrogen Utilization[J]. Chinese Journal of Eco-Agriculture,2007(05):34-37.

[3] Zhao Zhiqiang, Dai Fuchu, Min Hong, et al.[J/OL]. Rock and Soil Mechanics,2021(09):1-12[2021-08-18].http://kns-cnki-net.vpn. chd.edu.cn: 8080/kcms/ detail/42.1199.O3. 20210528.1411.002.html.

[4] Lu Tinghao. Soil Mechanics(Second edition)[M].Nan Jing: Hohai University Press,2011.

[5] Yang Weilin, Yang Xiaowei. Diference and Comparison between Laboratory Test and Water Injection Test of Permeability Coeficient [J]. Guangdong Water Resources and Hydropower, 2017,(1):42-45.

[6] Zhang Xiaoyou. Study on characteristics of saturated permeability coefficient of loess slope in Jingyang Nanyuan [D]. Changan University,2016.

[7] Li Ping. Study on the Triaxial Permeability Test of Saturated Loess [D]. Northwest Agriculture and Forestry University of Science and Technology,2007.