Exploration on mechanical test method of improved loess under dry-wet cycles

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Abstract: The stability of loess subgrade is affected by many factors. Dry-wet cycle is a common factor that causes damage to the strength of loess subgrade. In order to study the influence of dry-wet cycle on the stability of loess subgrade, reveal the mechanism of dry-wet cycle damage to the strength of loess subgrade, and study the performance of the loess under the dry-wet cycle, it is necessary to sample the loess soil samples in this area, and perform compaction test, dry-wet cycle test, unconfined compression test and scanning electron microscope test on the soil sample to analyze the influence of dry-wet cycle on the strength and microstructure of loess soil. In this way, the potential relationship between the microstructure and the strength of the soil can be obtained. The results show that the loess dry-wet cycle causes the loess's tensile strength and compressive strength to decrease with the increase of the number of dry-wet cycles. The dry-wet cycle effect gradually reduces the shear structural strength of the undisturbed loess and eventually disappears. Scanning electron microscope tests found that the humidification process caused slight movement of the particles, while the drying process resulted in permanent deformation of small pores.

Keywords: Loess; Dry-wet cycle; Mechanical properties; Microstructure.

1. Introduction

The loess is in the cyclical change of climate and seasons, and the soil is also in the cyclical state of alternating dry and wet receiving rainfall and evaporation at this time, and such alternating dry and wet have a great impact on the physical and mechanical properties of loess. Previous studies by scholars have shown that the loess that has undergone multiple drying and wet cycles will weaken the shear strength of the loess, the ability to resist deformation, and the structure of the loess will be destroyed. Therefore, the performance of the loess under the dry-wet cycle The research has an important impact on the construction of the loess area.

Study on the strength of loess under dry and wet cycles, Hu Wenle et al. [1] conducted a large number of consolidated and undrained triaxial tests and concluded that the shear strength is closely related to the water content, compactness and confining pressure. Barzegar [2] conducted a large number of experiments on reshaping soil by simulating the indoor dry-wet cycle environment. The results showed that in the dry-wet cycle of increasing drying, the softening of soil by humidification is an important factor in reducing soil strength. The repeated occurrence of the wet cycle will increase the intensity changes caused by the softening of the soil. Wang Li et al. [3] found through the direct shear test of loess that no matter how much the clay content of the loess is, as the moisture content increases, the c value of the sample first increases and then decreases, while the Φ value shows it is a linear decline. Wang Wei et al. [4] found through the study of remolded loess that the peak strength and residual strength of remolded loess are similarly affected by moisture content and normal stress, and the moisture content can be used to estimate the residual strength. AL-Homoud AS [5] found that the water-soil characteristic curve of expansive soil under dry-wet cycle conditions changes with the change of its water content, and the shear strength changes of soil samples with the same suction are also different. Wu Junhua [6] conducted repeated dry-wet shrinkage tests on reshaped expansive soils, and finally concluded that the repeated dry-wet shrinkage effects will significantly reduce the shear strength of the soil, and the attenuation of cohesive force is higher than Angle of internal friction. Cheng Jiaming et al. [7] studied the influence of dry-wet cycles on the shear strength of solidified loess through direct shear tests, and showed that the strength of solidified loess decreased overall after drying-wet cycles, but it was much higher than that of plain loess. Zhao Jingang et al. [8] established a fill slope model in Ankang expansive soil area, conducted dry-wet cycle tests on expansive soil slopes, combined with theoretical analysis and experimental research, and used dry-wet cycles to determine the dynamics of physical quantities of expansive soil slopes. The influence law is studied, and the research results show that, among the
factors that affect the moisture of expansive soil, sunshine and cloudy days are indirect factors, while stagnant water and rainfall are direct factors. Mu Huandong et al. [9] studied the influence of moisture content on the shear strength parameters and strength attenuation characteristics of loess under dry-wet cycles through direct shear tests. The shear strength is reduced, and the strength attenuation is most obvious when one dry-wet cycle is applied; the more the number of dry-wet cycles, the smaller the amplitude of strength attenuation. Yan Yajing et al. [10] studied the changes in the shear strength of unsaturated remolded loess and its parameters after being affected by soluble salt, and concluded that soluble salt has a significant non-linear weakening of the shear strength and cohesion of unsaturated loess.

For the study of the loess structure under the dry-wet cycle, Diel J et al. [11] believed that the dry-wet cycle not only affects the easily visible macroporous soil (> 8μm), but also affects the mesoporous soil. The lower the bulk density, the greater the change in macropores. Repeated wet and dry cycles did not cause random changes in the distance between particles and pores. Microstructural evolution of expansive clay during drying-wetting cycle [12] observed and analyzed and obtained the distribution of adsorbed water and capillary water, and measured the changes of adsorbed water and capillary water content with matrix suction during the drying-wetting cycle. The evolution of pores and macropores under suction is studied. It is observed that the micropores undergo permanent deformation during the dry-wet cycle. Ye Wanjun et al. [13] believed that with the progress of the dry-wet cycle, the contact form between paleosol particles gradually transitioned from surface-surface contact to edge-surface contact, and finally developed into edge-edge or point-surface contact. At the same time, the proportion of small pores gradually decreases, the content of large and medium pores gradually increases, the particle abundance value continues to increase, and the fractal dimension gradually decreases. Romero E et al. [14] found that during the dry-wet cycle, the soil microstructure changes significantly, accompanied by volume changes, which may strongly affect soil properties, such as compressibility, shear strength, and hydraulic conductivity. During the drying process, most of the shrinkage deformation occurs in the capillary zone, and the interfacial surface tension tightens the skeleton through capillary force. The discharge of pore water occurs sequentially from larger pores to smaller pores. The author divides water into three categories, capillary water, adsorbed water and strongly bound water. In the process of wet and dry cycles, capillary water is easier than adsorbed water. Discharge, and strongly bound water is always present. It also introduces the application status and development of two commonly used techniques for studying the microstructure of partially saturated soils, namely mercury intrusion method and environmental scanning electron microscopy. Research on the properties of lime-improved expansive soil under dry-wet cycles Qiu Qinyuan et al. [15] conducted dry-wet cycle experiments on cement-improved loess, and found that after 8 dry-wet cycles, the edge cracks of the 3% sample gradually expanded. When the sample is separated from the ring knife, the shrinkage is obvious, and the soil at the edge of the sample peels off more seriously, and there are large penetration cracks; the sample with 5% content has obvious shrinkage, and the number of cracks at the edge of the sample increases. The phenomenon of block spalling is more serious than the previous few times, but it can ensure the integrity of the sample as a whole, and there is no obvious penetration crack; the sample with 7% content is complete with a little shrinkage, but there is still no obvious crack, nor is there any block peeling occurs. Wang Fei et al. [16] used expansive soil and loess as the research objects. The shrinkage index line shrinkage rate and volume shrinkage rate of expansive soil decreased with the increase of the number of drying and wet conditions, and finally stabilized. Shi Gang et al. [17] selected samples from representative highway engineering test sites and applied SEM images to study the microstructure of loess. They found that the geological age changes from new to old, and the degree of weathering to soil has increased weakly. And the corresponding structure types mainly include four types of scaffolding macropores, embedded micropore micromagnet structure, flocculent, clotted cemented structure, and embedded microporous semi-cemented structure.

2. Experiment method

2.1 Compaction test method

Compaction test According to the "Code for Design of Highway Subgrade" [18], a heavy-duty compactor is used to carry out compaction tests on the modified expansive soil with different lime content. The preparation method of the dry compaction test sample for lime-improved expansive soil with different lime content. The preparation method of the dry compaction test sample for lime-improved expansive soil is:(1) After the soil sample is air-dried to a moisture content of less than 10%, it is passed through a 5 mm sieve, and the soil sample under the sieve is taken for later use. (2) Determine the moisture content of the air-dried soil sample and divide the soil sample into several parts (each soil sample is 2.5-3.0 kg). (3) After adding water to each soil sample to the set moisture content, seal it in a plastic bag for 24 hours so that the soil sample is fully infiltrated and the moisture content is uniform. (4) Perform compaction after mixing, and determine the maximum dry density and optimal moisture content of different samples according to the test method.

2.2 The method of improved soil preparation

The selected soil samples are dried, crushed, and sieved. Mix the admixture with the treated loess in proportion. Calculate the water quality according to the water content of the modified soil, add the weighed water to the mixture, stir it evenly, and let it stand in a humidifier for 24 hours. The moisturized mixture is placed in a mold for uniform compaction, and the mixture in the mold is compacted from both ends in three compactions. Use a demolding instrument to eject the test piece from the mold. In order to prevent moisture loss, seal the prepared sample with a plastic film and place it in a curing box (the temperature of the curing box is (20±1)°C, and the relative humidity is
(96±2%), in the humidity box Keep in good health for 7 days. Make the test piece with a degree of compaction greater than 95%, and then perform multiple freeze-thaw cycles on the soil sample. In the experiment, try to use the same batch of test pieces and perform different freeze-thaw cycles.

2.3 Test method of dry and wet cycle
According to the test results of the soil moisture content of the soil at the borrow site, and taking the depth of the soil into consideration, the main concentration range of the water content of the loess within this depth is to be simulated or measured [19].
Humidification, for samples that require a dry-wet cycle, the samples need to be humidified. First measure the quality and moisture content of the sample, calculate the amount of water that needs to be added to reach the predetermined moisture content, and then use a syringe to titrate the sample to add water, and after the sample reaches the predetermined moisture content, put the sample in a moisturizing cylinder and let it stand for 24 hours Above, make the moisture in the sample uniform. The dry-wet cycle is divided into two processes: drying and humidification. After drying and humidifying once, it is called a dry-wet cycle.
Dry, let the soil body stand for more than 24 hours, the sample with uniform moisture in the sample will be air-dried naturally, and the sample needs to be weighed at intervals. When the quality required by the lower limit moisture content is reached, stop air-drying and put it in a moisturizer Keep moisture in the cylinder for more than 24 hours to make the water in the sample evenly distributed.
After the sample is air-dried and humidified to the target moisture content, the soil sample is sealed and cured for 24 hours to ensure sufficient moisture transfer, and then the next dry-wet cycle of the sample is performed again [21]. For the long-term multi-period dry-wet cycle simulation, Huang D proposed a 30-day cycle and a 180-day dry-wet cycle simulation. Drying in a blast drying oven at 50°C for 24 hours achieves the purpose of dehumidification. Shake in 100 ml of distilled water for 5 minutes in a shaker, and let it stand for 24 hours to achieve the humidification effect.

3. Experimental results

3.1 The influence of dry-wet cycle on the strength of loess
The strength of loess is mainly divided into three parts: tensile strength, compressive strength, and shear strength.

(1) Tensile strength
The tensile stress-strain curve of loess is obviously different under the influence of moisture content and the number of wet and dry cycles, but they are all brittle failures, and the curve is basically a strain hardening type; the lower the soil moisture content, the stage of the stress-strain curve of loess The more obvious it is; the number of dry-wet cycles will not change the law of the stress-strain curve of loess under the same moisture content, but it will reduce the tensile stress and tensile strain of the loess, and as the moisture content becomes smaller, this decrease The more obvious the phenomenon.
The tensile strength of loess is obviously affected by the number of wet and dry cycles. With the increase of the number of wet and dry cycles, the attenuation amplitude of its tensile strength decreases. After one dry and wet cycle, the attenuation amplitude of the tensile strength of loess is the largest. It tends to be stable after the second and dry cycle.
(2) Compressive strength
Under the condition of uniaxial compression, the stress-strain curve of the loess sample increases nonlinearly, decreases rapidly after reaching the peak, and finally stabilizes to a certain value. The number of dry-wet cycles will not change the law of the compressive stress-strain curve of loess under the same moisture content, but it will reduce the ultimate compressive strain of loess, and the smaller the moisture content, the more obvious this reduction phenomenon.
The number of dry-wet cycles has a very obvious influence on the unconfined compressive strength of loess. The compressive strength decreases continuously with the increase of the number of dry-wet cycles. After one dry-wet cycle, the unconfined compressive strength of loess attenuates the most. However, with the increase of the number of wet and dry cycles, the attenuation amplitude gradually weakened, and it basically stabilized after several wet and dry cycles.
(3) Shear strength
The increase in the number of dry and wet cycles affects the shear strength index of loess. Under the same conditions, the increase in the number of dry and wet cycles and moisture content weakens the cementation of the loess particles, resulting in the shear strength, cohesion and internal friction angle of the soil. In loess with high moisture content, the reduction of cohesive force is much smaller than that of loess with low moisture content; the internal friction angle of undisturbed and remolded loess gradually increases with the increase in the number of dry and wet cycles Decrease, but not much. The attenuation value of the shear strength parameters of the undisturbed and reshaped loess after several cycles of drying and wetting is reflected, especially the attenuation value of the cohesive force is relatively large. The dry-wet cycle effect will gradually reduce the shear structural strength of the undisturbed loess, and eventually disappear, making its strength properties close to those of remolded loess.

3.2 Changes in microstructure
The study of soil microstructure has gradually changed from qualitative analysis to quantitative research. With the development of instruments, there are more and more testing methods. The combination of electron microscope and computer image analysis is a better method to study soil microstructure. You can get basically all the microstructure parameters of the soil. Without the effect of dry-wet cycle, the particles are tightly arranged, and the initial structure strength is greater. After being humidified, the bound water film
around the soil particles is thickened, reducing the sliding friction between the particles, causing slight movement between the particles; while in the drying stage, the continuous loss of moisture causes damage to the structure of the sample. Local pores increase, which leads to a decrease in occlusal friction between particles. After three dry-wet cycles, the internal structure of the soil sample has tended to a new stable equilibrium state, after which the cycle action has little effect on the strength of the soil. With the increase in the number of wet and dry cycles, the tiny pores inside the loess gradually become larger and the porosity increases [22].

During the dry-wet cycle, the soil microstructure changes significantly, accompanied by volume changes, which may strongly affect soil properties, such as compressibility, shear strength, and hydraulic conductivity. During the drying process, most of the shrinkage deformation occurs in the capillary zone, and the interfacial surface tension tightens the skeleton through capillary force. The discharge of pore water occurs sequentially from larger pores to smaller pores. The internal moisture of loess during the dry-wet cycle can be divided into three categories: capillary water, adsorbed water and strongly bound water. During the dry-wet cycle, Capillary water is easier to discharge than adsorbed water, and strongly bound water always exists. For saline loess, with the increase in the number of dry-wet cycles, the accumulated salt expansion continuously destroys the original structure of the soil, accompanied by the fragmentation of the particles, resulting in the gradual decrease of the occlusal friction of the soil, so the overall strength is continuously decreasing. Trend [23].

4. Conclusions

(1) The precautions in the loess dry-wet cycle experiment are summarized. Considering the actual situation of the project, the humidity of the test loess dry-wet cycle should be controlled to simulate the actual situation. The addition of admixtures may enhance the moisture retention capacity of the loess.

(2) Sort out some loess strength tests under dry-wet cycle conditions, introduce the methods and procedures of compaction test, as well as the humidification and drying methods in dry-wet cycle experiments, and the precautions in electron microscope scanning experiments.

(3) Summarized the changes in the microstructure of loess by the dry-wet cycle. The humidification process leads to slight movement of particles, while the drying process leads to permanent deformation of small pores. After several cycles of dry and wet, the internal structure of the soil sample has tended to a new stable equilibrium state, after which the cyclic effect has little effect on the strength of the soil.

References


