Effect of Water Sensitivity on Microstructure Characteristics and Deformation Mechanism of Q3 Loess

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Abstract. Microstructure characteristic of loess is an effective way to study the physical and mechanical characteristic of soil under different conditions. Water content in sample of Q3 loess is about 25%, the particle structure of the loess belonged to the granular structure type. CT scanning tests were performed on the sample before and after wetting. The changes of total number of pores, the maximum pore volume and the position of the centroid of pore of the sample were analyzed before and after wetting. The results showed that the soluble salts of loess have been dissolved after wetting. The volume of the pores of loess have been changed. Some increased, some decreased and the others closed in volume. The change of the number of pores indicated that the sample formed obvious saturated zone, transition zone, conduction zone and humid zones after wetting. These results revealed the characteristic and deformation mechanism of microstructure for Q3 loess.

Keywords: Q3 Less; microstructure; pore volume; characteristic of deformation.

1. Introduction

The microstructure of loess is one of the basic characteristics which reveals the formation conditions of loess, studies the physical and mechanical characteristics of soil under variety conditions. Natural particles in loess are mainly composed of powder particles for obvious large pores, and most of the soil particles are cemented by soluble salt crystals. he water sensitivity and dynamic vulnerability of loess are remarkable.

Rainfall infiltration is caused to dissolve the soluble salts in loess, then the micro-cracks in loess changed in a certain. The water content in loess has a great influence on cohesion and angle of internal friction, and the shear strength can sharply decrease when it encounters water. There are mainly two methods to study the collapsible of loess: firstly, the qualitatively or quantitatively [1-3] study the collapsible of loess from the opinions of the soil composition, microstructure characteristics and mechanical mechanism of the loess by laboratory tests. Polarized light microscopes [4] was used to conduct preliminary research on the structural of loess, and obtained some simple qualitative conclusions. Scanning electron microscope and mercury intrusion test [5-7] were used to conducted in-depth research on the microstructure characteristics and pore structure of loess, the classification of loess microstructure was proposed from different views, and were examined the relationship between microstructure and collapsible of loess. Experimental study [8-10] has been conducted to reveal quantitative on the microstructure of loess. Secondly, carrying out in-situ large-scale test pit immersion test or immersion load test, which can directly obtain the self-weight collapse deformation and the lower limit depth of the loess on the site [11-20]. However, the method is so relatively little development due to its high cost and time-consuming, the workload is large.

However, how does the structure of the Q3 loess change after the rain is humidified, how does the collapsible process occur, what is the microstructure deformation and its mechanism. In response to these problems, the microstructure deformation and mechanism of the Q3 loess after wetting was carried out to study. The microstructure type of loess was analyzed by the scanning electron microscope test. Thirdly, the sample of Q3 loess was scanned by CT, change micro-cracks in sample of Q3 loess were examined before and after wetting.

2. CT Scanning Test of Loess

2.1 Test Introduction

The Q3 loess contains a large number of pores is that the soil is one of the main characteristics. The microstructure is created during the formation and deformation of Q3 loess because of the production environment of loess and the geophysical and chemical effects in the process of diagenesis. The concentrated reflection of biochemical effects. Particle morphology, pore characteristics and degree of cementation are concentrated manifestations of the microstructure characteristics of Q3 loess. The dual-energy coal and rock scanning analyzer system is mainly composed of dual-energy X-ray sources, high-resolution amorphous silicon area array detectors, and computer 3D scanning to build an image processing system as shown in Figure 1.

Fig.1 Dual energy scanning analysis for coal and rock

2.2 The Sample of Q_3 Loess

The height of sample of Q3 loess is about 4.31cm, the diameter is about 1.78cm, the soil weight is 30.9g, and the moisture content of the sample before wetting is about 5%. According to the results of the field rainfall test, the sample was permeated with water content of about 25%. The sample before and after wetting is shown in figure 2.

Fig.2 The sample of Q_3 loess

3. Test Results

3.1 Analysis of the change of pore numbers in CT image before and after wetting

The main characteristics of collapsible Q3 loess are contained to large numbers of pores and large-size pores. They can be divided into three types according to the pore size: ultrafine pores, fine pores and large pores. Ultrafine pores and fine pores are also both called intergranular pores. The intergranular pores are made up of main body of loess porosity, and the pores are slightly larger than the diameter of particle in loess or aggregates. The occurrence of loess collapsible causes to damage structure of the loess, and causes these intergranular pores to increase, decrease, or tend to close, finally, the particles of loess would slip and fall into the large pores.

3.2 Analysis of the maximum pore volume in CT image before wetting

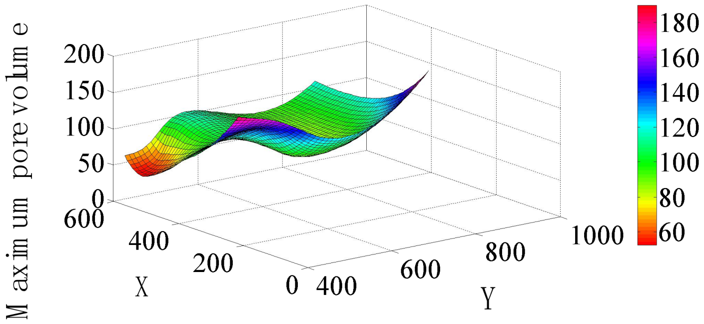

Fig. 3 The maximum pore volume before wetting

3.3 Analysis of the maximum pore volume in CT image after wetting

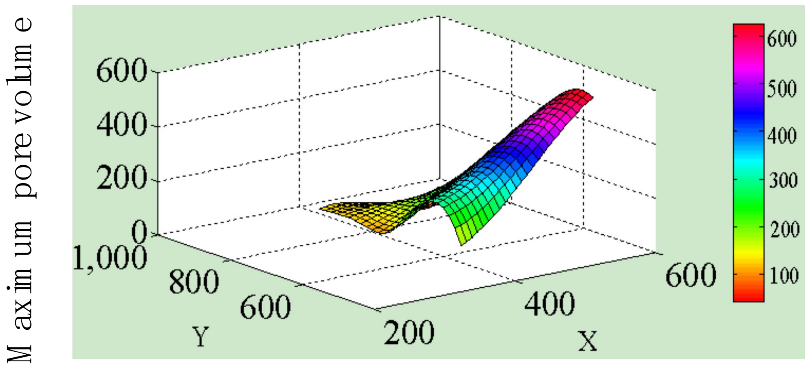

Fig. 4 Maximum pore volume after wetting

3.4 Analysis of the change of pore numbers in CT image before and after wetting

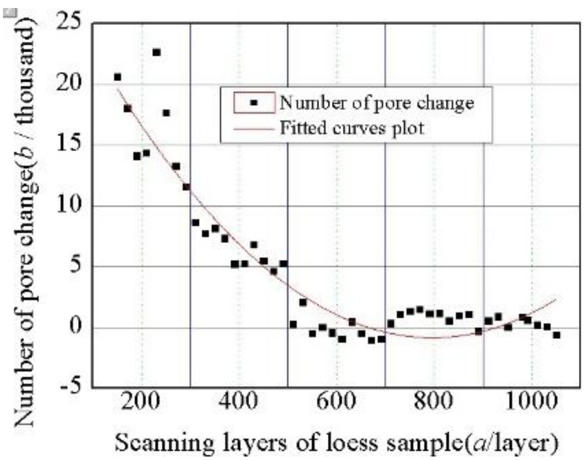

Fig. 5 The number of pore change before and after wetting

$$b = 0.049a^2 + 78.129a - 20252 \quad (1)$$

Where b is the numbers of pore change, a is the scanning layers of sample of loess.

3.5 Comparison of the largest pore volume of loess before and after wetting

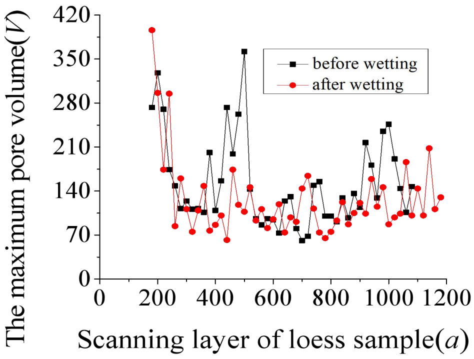

Fig. 6 The maximum pore volume before and after wetting

3.6 Analysis of the maximum volume change of loess before and after wetting

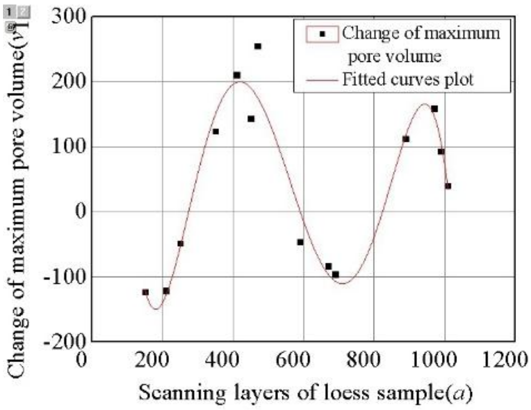

Fig. 7 The number of maximum pore volume change before and after wetting

$$V_1 = 3E-14a^6 - 2E-10a^5 - 4E-07a^4 - 0.0004a^3 + 0.1664a^2 - 31.222a + 1921.1 \quad (2)$$

Where V1 is change of the maximum pore volume before and after wetting, a is the scanning layers of sample of loess.

4. The range of collapsible loess

The influence of collapsible range (wetting radius) can be calculated by the following formula [24]:

$$r = H(0.5 + m_\beta \tan\beta) \quad (3)$$

Where r is collapsible radius after wetting, H is layer thickness of collapsible loess, mβ is the coefficient of increase of water spreading to the side because of the water permeability of each layer and interlayer is different, the value is from 1 to 2. β is the diffusion angle from the flooding site to the side flooding, β=35° for loess and loess-like silt, and β=50° for loess-like silty clay.

The penetration depth of Q3 loess is directly related to its micro-cracks, which is also the fundamental factor to determine the penetration depth. Once Q3 loess was wetted, water would first infiltrate along the cracks in loess, and the larger penetration of the cracks is, the deeper infiltration is. The soluble salt content of loess also has an important effect on the infiltrating depth. After wetting, some of the soluble salts of loess would dissolve, new cracks would formed, then the infiltrating depth would increase.

5. Discussion

Figures 3 and 4 showed that the change of the maximum pore volume of Q3 loess before and after wetting respectively. Some of pore volumes of loess increase significantly after wetting, it indicated that the soluble salt in loess have been dissolved and new micro-cracks were formed.

Figure 5 showed that the numbers of pores increased significantly in the upper half of the sample after wetting. The increase in the number of pores decreases rapidly with the increase of the height of the sample. Near the middle of the sample, the pores after wetting are smaller than the number of pores before wetting. The number of pores after wetting remains basically constant. This indicated that the soluble salt in loess has a close relationship with the height of the sample. The closer to the end of the sample, the higher the degree of dissolution. The distribution of the largest pores along the height of the sample was relatively uniform after wetting, and new pores were formed after wetting, and from the top to the bottom of the sample, it indicated that the original pores increase, decrease or close after the soluble salt was dissolved in water. Part of the pores were connected to form new seepage channels, and water can infiltrate from these pores more easily.

Figure 7 showed that the change of the maximum pore volume. Some increase and some decrease after wetting. The change of the maximum pore volume fully showed that the micro-cracks of loess have changed after wetting. It is an effective way and means to analyze collapsible loess.

6. Conclusions

The laws of changes in micro-cracks of Q3 loess before and after wetting was examined by scanning electron microscope, CT scanning analysis of sample of Q3 loess before and after wetting, characteristic and mechanism of deformation for microstructure were revealed after wetting.

The particle morphology, microstructure, porosity and fissure of Q3 loess changed significantly after wetting. The large pores decreased while the small pores increased, and the soil density increased.

The microstructure and deformation mechanism of Q3 loess change significantly, resulting in the decrease of Q3 loess shear strength, which is the internal reason for the decrease of mechanical properties of Q3 loess after wetting.

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