Microstructure Characteristics and Quantitative Analysis of Collapsible Loess in Xining Area

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Abstract: According to the confined compression test in Xining area, the variation law of pressure on the collapsible deformation and compress deformation of loess is analyzed. The qualitative and quantitative analysis of the microstructure of loess samples before and after collapsing is carried out by electron microscopy. The relationship between the microstructure of the loess sample and the collapsible deformation is analyzed. The results show that: (1) with the increase of pressure, the deformation and compression of loess collapsing gradually become smaller, the soil is compacted, the strength is increased, the compressibility is weakened, the collapsibility is weakened or no collapsibility; (2) with the increase of pressure, the microscopic image observation of the sample before immersion, the arrangement of the skeleton particles becomes very tight, and the pore shape changes from large become small. As the pressure continues to increase, the microstructure of the sample gradually becomes dense; (3) the pressure increases with the increase of pressure before and after immersion in water. The arrangement gradually became stable, the particle distribution gradually concentrated and the degree of agglomeration became higher, and the proportion of pore area gradually decreased. The macroscopic collapse deformation and compression deformation of the loess before and after water immersion were consistent.

1. Introduction
The loess weakly cemented Quaternary sediment, loess is very complex in its material composition, particle shape, arrangement, contact and connection. Its existing structural state is a comprehensive product of its entire historical formation process, directly affecting the physical and mechanical properties of loess. Researchers used the single-line method to determine the collapsibility under different pressures, and analyzed the soil samples before and after collapsing by electron microscopy [1-2]. The fundamental reason for the change of macroscopic physical and mechanical properties of soil is the structural change of soil. Therefore, it is very important to study the microstructure of soil to provide a basis for improving the engineering properties of soil [3-6]. The microstructure of the soil sample is observed, and the regression analysis method is used to obtain that the collapsibility coefficient of the loess increases with the pore fractal dimension and the unsaturated pore porosity. The unsaturated pore is the main reason for loess collapsing [7-10]. Many scholars have done a lot of research work on the properties and distribution characteristics of loess engineering, but the past research focuses on the typical loess areas such as Gansu, Henan, and Shanxi. The research on the distribution law and engineering characteristics of the loess in Qinghai is relatively high. Therefore, this paper studies the combination of indoor collapsibility test and scanning electron microscopy in the
Xining loess of Qinghai, and studies the macroscopic collapsible deformation of loess under different pressures in Qinghai and the microstructure before and after soaking.

2. Test soil and method

2.1 Test soil
The test soil was taken from a construction site in Xining, and the soil depth was 5m. The soil structure was dominated by loess silty clay. The soil was yellowish brown and the pores were relatively developed. The physical properties of the soil are shown in Table 1.

| Depth of soil /m | Natural moisture content /% | Soil specific gravity | Liquid limit /% | Plastic limit /% | Plasticity index | Dry density g/cm³ | Particle composition /% |
|-----------------|-----------------------------|----------------------|----------------|-----------------|-----------------|------------------|-------------------------|
| 5               | 10.3                        | 2.70                 | 28.36          | 13.52           | 16.74           | 1.61             | 87.4                    |

2.2 Test methods

2.2.1 Indoor collapsibility test
The test instrument is a WG-type single-lever consolidation instrument (Fig.1). The single-wire method is adopted. The sample size is 50cm² and the height is 20mm. The test termination pressure is 200kPa, 400kPa and 600kPa respectively.

2.2.2 Microscopic test
This test instrument (Fig.2) JSM-6610LV electron microscope quantitatively analyzes the relationship between macroscopic collapsible deformation and compression deformation and microstructure characteristics of loess before and after different pressures.

3. Analysis of test results

3.1 Characteristics of loess collapsibility curve and compression curve

It can be seen from Fig. 3 and Fig. 4 that the void ratio is an index reflecting the degree of soil density, and is the ratio of the pore volume to the solid volume in the soil. One of the characteristics of loess is that it is rich in pores, and because of so many pores, it provides space for loess collapsing. The difference in the size and structure of the void ratio has a great influence on the strength and collapsibility of the loess itself. The loess with large pore ratio and large pore structure is easily destroyed by external force and internal force, and it is easy to collapsible. The loess with good porosity and small cementation is not easy to collide under the same force. With the increase of pressure, the amount of collapsibility also gradually increases, and the trend of change is roughly three
stages: the first stage (0kPa~200kPa), the loess collapse deformation begins to develop and the slope is large, and the corresponding void ratio decreases. Large, called the rapid development stage of loess collapsing; the second stage (200kPa~400kPa), the development slope of loess collapsible deformation is relatively flat, the corresponding rate of decline of pore ratio is gradually flat, called the slow development stage of loess collapsing; the third stage (400kPa~600kPa), the loess collapse deformation is stable development, the corresponding porosity ratio is gradually stable, which is called the stable development stage of loess collapsing.

3.2 Microstructure changes of loess under different pressures

Under the pressure of loess, with the passage of time, the continuous change of microstructure is one of the main factors causing the collapsibility of loess. The problem of collapsibility of loess is mainly due to the relative shifting of the internal microstructure unit. Therefore, to explain the cause of loess collapsibility, it is necessary to systematically study the microstructural changes of loess.

3.2.1 Qualitative analysis of loess microstructure under different pressures

![Microstructure changes of loess before and after water immersion under different pressures](image)

The micro-images with magnification of 300 times (Fig.5) were compared and analyzed. The microscopic images of the samples before immersion were observed. The structure of the undisturbed soil samples was loose, the pores and particles were clearly distinguished, and the particle contours were clear. After the sample is immersed in water, the arrangement of the skeleton particles becomes very tight, and the pore shape changes from large become small. As the pressure continues to increase, the microstructure of the sample gradually becomes dense. The contact relationship between the particles occurred mainly by the contact of the stent, and gradually changed to the stent and the mosaic contact. The final change was mainly the mosaic contact, and the contact relationship between the skeleton particles was changed from point to surface contact to face-face contact. With the increase of pressure, the microscopic image of the sample after immersion shows that the number of tiny pores is significantly reduce, the pores are filled with a large number of fine particles. At the same time, it can be seen that the microstructure characteristics of loess samples under different pressures are also different. The sample that was collapsible at low pressure (200kPa) also retained part of the original pore structure, but when the pressure was increased to 600kPa, the original pore structure was almost completely destroyed, and the microstructure was more compact. Therefore, under the combined action of pressure and water, the pores in the loess will change continuously, the number of tiny pores that will gradually decrease, and the number of small pores and tiny pores will gradually
increase.

3.2.2 Quantitative analysis of loess microstructure under different pressures

Analysis of Table 2 and Figure 6 for the quantitative parameters of the microstructure of loess samples before and after the infiltration of different depth collapsible loess, the following results can be obtained:

| Depth (kPa) | Soil state | Area ratio | Average form factor | Probability entropy | Distribution fractal dimension |
|------------|------------|------------|---------------------|---------------------|-------------------------------|
|            | Before immersion | 14.32% | 0.395 | 0.991 | 3.347 |
|            | After immersion | 10.26% | 0.373 | 0.989 | 3.254 |
| 200kPa     | Before immersion | 12.65% | 0.384 | 0.990 | 3.301 |
|            | After immersion | 9.34% | 0.367 | 0.984 | 2.974 |
| 400kPa     | Before immersion | 9.37% | 0.373 | 0.988 | 3.204 |
|            | After immersion | 7.28% | 0.358 | 0.982 | 2.736 |
| 600kPa     | Before immersion | 8.49% | 0.352 | 0.987 | 2.930 |
|            | After immersion | 5.41% | 0.345 | 0.981 | 2.535 |

Figure 6. Curve of quantitative parameters of microstructure before and after loess immersion in water under different pressures

(1) Pore area ratio. As the pressure increases, the area ratio of the particles gradually increases, and the area ratio of the pores gradually decreases, which corresponds to the fact that the macroscopic pore ratio gradually decreases as the pressure increases. The proportion of the pore area after immersion is faster than the ratio of the area of the pores before immersion, indicating that the combined action of pressure and water leads to the gradual packing of the particles, and the connectivity and size of the pores in the soil also change. The interstitial pores are destroyed, resulting in a continued decrease in the proportion of pore area after immersion.

(2) Average shape factor. With the increase of pressure, a small amount of clot-like particles exist in the loess before immersion, and the particle shape is relatively rounded. The circularity of the single-mineral particles is better, and the corresponding circularity is better. The loess layer after immersion has more granules, so the shape of the particles and pores is complicated, and the circularity is small, indicating that the action of pressure and water makes the arrangement of some particles denser and pores. The area is reduced, the number of pores is increased, the circumference is increased, and the circularity of the pores is reduced.

(3) Probability entropy. With the increase of pressure, the order of particles changes before and after immersion, and the tiny particles move in a certain degree of pore direction. After immersion, the order of pores becomes better than that before immersion, indicating the joint effect of force and water. The pore arrangement is gradually stabilized.

(4) Distribution fractal dimension. With the increase of pressure, the fractal dimension of the particles increases gradually, and the fractal dimension of the pores decreases gradually. The distribution of fractal dimension after immersion is lower than that before immersion, indicating that the pressure and water act to distribute the particles. It is more concentrated and more organized, and
the distribution of pores is weaker than that of dispersion and grouping.

4. Conclusion
Through the indoor collapsibility test, the deformation and deformation of loess in different pressures in Xining area were analyzed. The microstructure of loess samples before and after collapsing was qualitatively and quantitatively analyzed by electron microscopy. The variation of collapsible deformation characteristics was as follows:

(1) The pressure has a significant influence on the collapse deformation and compression deformation of loess. With the increase of pressure, the amount of collapse deformation and compression under the same pressure gradually decrease, and when the pressure increases to a certain extent, the soil particles was compacted and the structure of the soil changes. The collapse deformation of loess shows weakening of compression and weakening of collapsibility.

(2) With the increase of pressure, the microscopic image of the sample before immersion is observed. The structure of the undisturbed soil sample is relatively loose, the pores and particles are clearly distinguished, and the particle contour is relatively clear. After the sample is immersed in water, the arrangement of the skeleton particles becomes very tight, and the pore shape changes from large become small. As the pressure continues to increase, the microstructure of the sample gradually becomes dense.

(3) With the increase of pressure, the microstructure of loess shows that the pore arrangement gradually becomes stable, the particle distribution is gradually concentrated, the degree of agglomeration becomes higher, and the proportion of pore area gradually decreases. Before immersion, the soil particles are compressed and compacted. The compressibility is gradually weakened; after immersion in water, due to the combined action of water and pressure, the soil structure gradually becomes denser and the stability is gradually enhanced, and the collapsibility is also weakened or not collapsible. Therefore, the microstructural changes of loess before and after water immersion are consistent with the macroscopic humidification deformation of loess.

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