Study on Collapsible Deformation and Microstructure of Loess in Xining Area

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Abstract: The collapsible loess in Xining area was tested by confined compression test to analyze collapsible and compression deformation of the loess. The researchers used electron microscopy to qualitatively analyze the microstructure of the loess samples before and after collapse. A comprehensive analysis of the relationship between the microstructure of the loess sample and the collapse deformation. The results show that: (1) with the increase of depth, the amount of collapse deformation and compression under the same pressure gradually become smaller, the soil is compacted, the strength is increased, and the compressibility and collapsibility are weakened; (2) due to the influence of loess stress history on its structure and collapsibility, with the increase of depth, the 6m loess exhibits less collapsible deformation and compressive deformation than the 3m loess; (3) with the increase of depth before and after immersion, the arrangement of pores tends to be stable, the particle distribution is gradually concentrated, the degree of agglomeration becomes higher, and the proportion of pore area gradually decreases. The collapsible deformation and compression deformation of loess before and after water immersion are consistent with the microstructure changes.

1. Introduction
Due to the common engineering accidents caused by the collapsibility of loess, many scholars have studied the collapsibility of loess. As a typical regional special soil, the study of loess's macroscopic mechanical characteristics and microstructure is the development trend of loess soil mechanics research. The scholars analyzed the method of determining the collapsibility of collapsible loess by calculating the overburden pressure value and the calculation of the collapsibility coefficient in the experiment[1]. By the indoor collapsibility test to evaluate the collapsibility and the collapsibility coefficient and its physical and mechanical data of the loess in the region are obtained [2-3]. Quantitative analysis the micro-structure of loess soil before and after water immersion, it is concluded that the effect of overhead pores is large, sensitive to the action of water, and the large pores become in the process of collapsing [4-8]. Researcher used scanning electron microscopy to study the pore characteristics of compacted loess before and after collapsing, and observed the microstructure of soil samples by scanning electron microscopy and used regression analysis to obtain that the collapsibility coefficient of loess increased with the increase of non-saturated pore porosity[9-10]. Due to the special environment and formation process of loess, the loess has obvious regional characteristics. Therefore, for the collapsible loess in Xining area, the influence of depth on the collapsible deformation of loess in Xining area is analyzed by the double-line method and combined with electron microscopy, and the microstructure of loess samples before and after immersion was quantitatively analyzed. Therefore, the law of collapsible deformation is analyzed for the micro-structure changes of loess in Xining area.
2. Test plan and method

2.1 Test soil
The test soil is taken from a construction site in Xining City. The soil structure is mainly composed of loess silty clay. The particles are relatively uniform, no layering, vertical joint development, more wormholes and plant residues, and small and less calcareous tuberculosis. The physical property indicators 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 /% |
|-----------------|-----------------------------|----------------------|----------------|----------------|------------------|------------------|-------------------------|
| 3               | 10.5                        | 2.72                 | 29.22          | 12.36          | 16.86            | 1.43             | 87.3                    | 12.7                    |
| 4               | 10.8                        | 2.72                 | 28.45          | 13.42          | 15.03            | 1.44             | 88.6                    | 11.4                    |
| 5               | 11.5                        | 2.72                 | 28.97          | 13.13          | 15.84            | 1.43             | 88.1                    | 11.9                    |
| 6               | 11.7                        | 2.72                 | 29.31          | 12.57          | 16.74            | 1.44             | 87.5                    | 12.5                    |

2.2 Test plan

2.2.1 Collapsing test
According to the "Building Code for Collapsible Loess Areas" GB 50025-2004, the test instrument is a WG-type single-lever consolidation instrument, which adopts the two-wire method. The sample size is 50cm², the height is 20mm, and the test pressure is 12.5kPa, 25kPa, 50kPa, 100kPa, 150kPa, 200kPa, 300kPa, 400kPa.

2.2.2 Microscopic test
The JSM-6610LV electron microscope was used to analyze the relationship between the deformation and compression deformation of the loess and the microstructure characteristics of the loess before and after the collapsing.

3. Test results and analysis

3.1 Characteristics of loess collapsibility curves at different depths

Figure 1 shows the relationship between the coefficient of collapse and the pressure at different depths, by analyzing the characteristics of the curve. It is found that as the pressure and depth increase, the trend of the collapsibility coefficient can be divided into three stages. In the first stage, the slope of the curve increases with the increase of pressure, and the collapsibility coefficient increases rapidly. It indicates that under the joint action of force and water, the loess structure is destroyed and the soil is
compacted, resulting in deformation. The second phase, the curve trend becomes flat, indicating that after the first phase of the compaction process, the growth rate of the collapsibility coefficient gradually slows down after the pressure is continued. In the stage, with the further increase of pressure, the structure after the compaction of the soil is destroyed, the collapsibility coefficient continues to grow and the growth rate is slower. This phenomenon indicates that the formation of loess has a long geological history process. The historical stress of loess is mainly due to its overlying load. It can be seen from Fig. 1 that the 3m soil is a loose structure, the connection strength between the particles is weak, and the 6m soil is relatively dense with the 3m soil, and the structure is relatively stable due to the overlying load. The loading history of loess affects structural features and collapsible deformation characteristics. Therefore, the loess gradually decreases in compressibility and collapsibility from top to bottom in the vertical direction or does not collapse.

It can be seen from figure 2 that in the confined state, as the pressure increases, the soil is gradually compacted, and the void ratio is gradually reduced; the thickness of the soil layer is gradually reduced, and the ability to resist deformation is weaker. The void ratio is reduced, and the corresponding e-logp curve is lower. Compared with the sedimentary environment and stress history at different depths, the depth is 3m. The pore ratio increases with the increase of pressure, and the slope gradually increases. In the soil layer with a depth of 6m, the pore ratio is relatively gentle with the pressure. In the overall analysis, as the depth increases, the void ratio of the soil decreases accordingly. From the p-δs and e-logp curves of different depths, the collapsibility of loess is closely related to the self-weight pressure. As the depth increases, the pressure on the soil is greater, and the pore ratio is relative. The soil gradually becomes denser, and the structural strength of the soil is greater, and the collapsibility tends to decrease with the increase of the buried depth of the soil sample.

3.2 Microscopic image analysis of loess at different depths

3.2.1 Qualitative analysis of microscopic images of loess at different depths

Fig. 3 shows the microscopic picture of the original undisturbed loess at different magnifications before and after 500 times of water immersion, and observes the particle arrangement, connection mode and pore morphology et al. It can be seen from Fig. 3 that before the water immersion in the loess samples of different depths, the soil sample structure is loose, the pores and particles are clearly distinguished, and the particle contour is relatively clear. When force and water work together, the arrangement of the skeleton particles is compacted, and the pore morphology changes from large to small; the contact relationship between the particles occurs mainly by the contact of the stent, and gradually changes to the stent and the mosaic contact, and the final change is the mosaic contact. Mainly, the contact relationship between the skeleton particles is mainly changed from point-to-surface contact to surface-surface contact.
The particle tightness of the 6m depth is larger than the depth of 3m. Because as the depth of the soil sample increases, the overburden pressure of the soil sample gradually increases, making the arrangement between the particles more dense. With the increase of depth, the upper soil layer contacts more than the lower soil layer, while the lower soil layer has more contact, so the compressibility and collapsibility of the upper soil layer are larger. The pores in the loess have large pores, overhead pores, and intergranular pores [9]. Large pores and overhead pores have great influence on compressibility and collapsibility. In particular, the number and configuration of overhead pores. With the increase of depth, the upper soil layer has more open pores than the lower soil layer, so its compressibility and collapsibility are also larger.

3.2.2 Quantitative analysis of microscopic images of loess at different depths
The particle and fissure image recognition and analysis system (PCAS) software was used to quantitatively analyze the microscopic structure pictures of loess with different magnifications of 300, reflecting the variation of depth and the geometry and distribution of particles and pores before and after immersion in the loess. Dimensional and other changes, Table 2 gives the quantitative parameters of microstructure under different pressures, Figure 4 is the quantitative parameter changes of microstructure before and after different depths of water immersion curve.

| depth | Soil state   | Area ratio | Average form factor | Probability entropy | Distribution fractal dimension |
|-------|--------------|------------|--------------------|---------------------|-------------------------------|
| 3m    | Before immersion | 13.19%     | 0.382              | 0.991               | 3.338                         |
|       | After immersion | 8.13%      | 0.362              | 0.988               | 3.036                         |
| 4m    | Before immersion | 11.66%     | 0.375              | 0.990               | 3.252                         |
|       | After immersion | 7.82%      | 0.354              | 0.983               | 2.888                         |
| 5m    | Before immersion | 9.82%      | 0.364              | 0.989               | 2.932                         |
|       | After immersion | 6.31%      | 0.342              | 0.981               | 2.485                         |
| 6m    | Before immersion | 8.61%      | 0.355              | 0.987               | 2.844                         |
|       | After immersion | 5.96%      | 0.322              | 0.980               | 2.335                         |

Analysis of Tab.2 and Fig. 4 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

Fig 4. Quantitative parameter variation curve of microstructure before and after immersion in different depths.
obtained:

1) Average shape factor. With the increase of depth, the circularity of the pores before and after immersion gradually decreases. The circularity of the particles after immersion is relatively flat with respect to the circularity of the pores before immersion.

2) Probability entropy. With the increase of depth, the order of particles before and after immersion deteriorates, and the tiny particles move in a certain degree of pore direction. After immersion, the order of pores gradually becomes better than that before immersion, indicating that the action of water makes the pore arrangement gradually become stable.

3) Distribution fractal dimension. With the increase of depth, the fractal dimension of the particles increases gradually, and the fractal dimension of the pores gradually decreases. The distribution of fractal dimension after immersion is lower than that before immersion, indicating the distribution of particles by pressure and water.

4) Pore area ratio. With the increase of depth, the proportion of the former pore area decreases greatly, indicating that the combination of pressure and water leads to the dense arrangement of the particles, which causes the connectivity and size of the pores in the soil to change, and the voids between the soil particles are destroyed, resulting in The proportion of pore area after immersion continues to decrease.

4. Conclusion
(1) The depth has a significant effect on the collapsible deformation and compression deformation of loess. With the increase of depth, the amount of collapsible deformation and compression under the same pressure gradually decreases, and when the depth increases to a certain extent, the soil particles are compacted. The soil structure changes, and the loess collapse deformation shows weak compression, weak collapsibility or no collapsibility.

(2) Due to the influence of loess stress history on its compressibility and collapsibility, with the increase of depth, the overburden load of soil is larger and the void ratio is relatively smaller. 6m loess and 3m loess show collapsible deformation and compressibility are relatively weak.

(3) With the increase of depth before and after immersion, the microstructure of loess showed that the pore arrangement gradually became stable. Before immersion, the soil particles were compressed. When compacted, its compressibility gradually weakens. 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.

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