Experimental study on permeability and expansion characteristics of expansive soil

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Abstract. Expansive soil is used as a high-plastic clay, the bearing capacity is gradually attenuated due to the penetration of water, which greatly limits the application range of practical engineering. In this paper, the permeability and expansibility test of remolded soil and undisturbed soil in expansive soil were carried out. Ability coefficient of remolded soil and undisturbed soil under different overburden values was compared and analyzed. Overburden load, head height and water content were studied. The effect of the rate on the permeability coefficient of remolded soil and further analysis of the expansion and expansion forces at different initial moisture contents The results show that the permeability coefficient of remolded soil and undisturbed soil decreases with the increase of overlying load. As the water content increases, the permeability coefficient decreases first within a certain range. After reaching a certain level, the permeability coefficient gradually increases. As the initial water content increases, the amount of expansion progressive decreases and the expansion force progressive decreases.

1. Introduction
Expansive soil is a kind of unsaturated, structurally unstable regional high plastic clay with mineral components mainly composed of montmorillonite and illite [1-5]. Nsion and contraction deformation, water immersion capacity attenuation and dry shrinkage crack development. Studying the engineering characteristics of expansive soil and analyzing the characteristics of expansive soil are of great significance for practical engineering construction [6-9].

This paper mainly analyzes the permeability properties of remolded soil and undisturbed soil through three sets of experiments.

2. Permeability test results and analysis

2.1. Undisturbed soil permeability coefficient change
It can be seen from Figure 1 that for the same set of tests, when the overlying loads are 0, 100, 200, 300, and 400 kPa, the permeability coefficients are 6.19×10⁻⁷ cm/s, 3.23×10⁻⁷ cm/s, 2.31×10⁻⁷ cm/s, 9.69×10⁻⁸ cm/s, 7.15×10⁻⁸ cm/s, with the increase of the overlying load, the permeability coefficient decreases gradually. When the load is small, the permeability coefficient increases with the overlying load. Large and rapid reduction, the permeability coefficient decreases with the increase of the
overlying load when the load is large. The permeability coefficient shows a nonlinear law with the change of the overlying load, and the rate of change decreases with the increase of the load.

2.2. Remodeling soil permeability coefficient change

The result of remodeling destroys the flocculated aggregates. It can be seen from Figure 1 that when the overlying loads are 0, 100, 200, 300, and 400 kPa, the permeation coefficients are 8.98×10^{-8} cm/s, 5.26×10^{-8} cm/s and 3.11×10^{-8} cm/s. The permeability coefficient decreases with the increase of the overlying load. The effect of infiltration on remolded soil is mainly through the compaction effect to change its pore ratio, and the change of pore ratio in the soil causes permeability change.

2.3. Comparison of permeability coefficient between undisturbed soil and remolded soil

The above two experimental results were compared to study the effect of remodeling on the permeability coefficient of expansive soil. It can be seen from Figure 1 that when the overlying load is 0, the permeability coefficient of the undisturbed soil is 6.19×10^{-7} cm/s, the permeability coefficient of the remolded soil is 8.98×10^{-8} cm/s, and the permeability coefficient of the undisturbed soil is greater than that of the remolded soil. The coefficients are approximately one order of magnitude difference. This is mainly due to the natural pores and micro-cracks in the undisturbed soil, which provides a good channel for the seepage of water. The remolded soil destroys the structure of the soil and redistributes the soil particles through compaction. From the perspective of the whole trend, the permeability coefficient of undisturbed soil varies greatly with the overlying load curve, and the remolded soil is relatively flat. For the application of a large overburden load from the remolded soil, the permeability coefficient of the undisturbed soil could not be achieved, indicating that the undisturbed soil has a large compactness in the deposition for a long time.

![Comparison of permeability curves between original and remolded soils](image)

2.4. Influence of overlying load on permeability coefficient of remolded soil

On the basis of the above tests, the variation law of the permeability coefficient of remolded soil with different overburden loads was further analysed. According to the experimental results, it can be seen from Figure 2 that when the overlying load is 0, 100, 200, 300, 400 kPa, the permeability coefficient of different dry density remolded soils decreases with the increase of the overlying load, and the dry density is smaller. The sample with a density of 1.55 g/cm³ has a permeability coefficient greater than 1.65 g/cm³ and greater than 1.75 g/cm³. It can be seen from Figure 3 that the permeability of the remolded soil decreases sharply with the increase of the dry density, indicating that the dry density is the most significant factor affecting the permeability. As the dry density increases, the porosity in the soil decreases, the penetration becomes difficult, the permeability coefficient decreases, and the faster the dry density changes, the slower the change in the permeability coefficient. Under the same density, the permeability coefficient decreases with increasing pressure.
Figure 2. Influence of overlying load on the permeability coefficient of remolded soil

Figure 3. Influence of dry density on permeability coefficient of remolded soil

3. Expansive test results and analysis

Figure 4 shows the relationship between water content and expansion. It can be seen from the experimental results that the initial water content is 4%, 7.5%, 10.6%, 14.3%, 18.3%, and the expansion amounts are 0.534 mm, 0.312 mm, 0.115 mm, 0.056 mm, 0.011 mm, as the initial water content increases, the amount of expansion gradually decreases. The reason for the above phenomenon is that the initial water content is increased by increasing the amount of water during the test, the moisturizing time is long, which causes the partial expansion amount to have occurred. The more the initial water content increases, the more the expansion amount is released and the subsequent expansion, the smaller the amount. It can be seen from Figure 8 that the relationship between the amount of expansion and the initial water content can be better in accordance with the index form.
On the other hand, it can be seen from Table 1, when the initial water content is small, increasing the initial water content causes the amount of expansion to decrease sharply; when the initial water content is large, increasing the initial water content causes a smaller amount of expansion. The curve is relatively flat. This indicates that the amount of expansion is mainly manifested in the lower stage of water content, the influence of the change in water content on the amount of expansion is weakened. This may be due to the fact that the expansion of the mineral particles in the low water content mainly occurs in the lattice expansion. As the water content increases, the latter mainly expands between the particles, and the lattice expansion is the main part of the expansion.

**Table 1. Experimental results of expansion**

| Water addition | Actual moisture content (g) | Expansion amount (mm) | Expansion limit water content (g) |
|----------------|-----------------------------|-----------------------|----------------------------------|
| 0%             | 0.04                        | 0.534                 | 0.186                            |
| 5%             | 0.075                       | 0.312                 | 0.183                            |
| 10%            | 0.106                       | 0.115                 | 0.180                            |
| 15%            | 0.143                       | 0.056                 | 0.179                            |
| 20%            | 0.183                       | 0.011                 | 0.192                            |

In order to further obtain the relationship between Δw and Δδ, Δw and Δδ were calculated based on the initial water content of 4%, and the calculation results are shown in Table 2.

**Table 2. Calculated values of Δw and Δδ with initial water content of 4% as the base point**

| Initial water content (g) | Δw  | Δδ  |
|---------------------------|-----|-----|
| 0.04                      | 0.00| 0.00|
| 0.075                     | 0.035| 0.222|
| 0.106                     | 0.066| 0.419|
| 0.143                     | 0.103| 0.478|
| 0.183                     | 0.143| 0.523|

Δw and Δδ were calculated based on the initial water content of 7.5%, the calculation results are shown in Table 3.
Table3. Calculated values of $\Delta w$ and $\Delta \delta$ with initial water content of 7.5% as the base point

| Initial water content (g) | $\Delta w$ | $\Delta \delta$ |
|--------------------------|------------|-----------------|
| 0.075                    | 0.000      | 0.000           |
| 0.106                    | 0.031      | 0.197           |
| 0.143                    | 0.068      | 0.256           |
| 0.183                    | 0.108      | 0.301           |
| 0.075                    | 0.000      | 0.000           |

It can be seen from Tables 2 and 3 that $\Delta w$ and $\Delta \delta$ are calculated based on the initial water content of 4% and 7.5%, respectively, and the relationship between $\Delta w$ and $\Delta \delta$ is fitted. The $\Delta \delta$ and $\Delta w$ are better than half at different initial water contents. Logarithmic relationship, the equation is Equation: $\Delta \delta=a\ln(\Delta w)+b$, Where $\Delta \delta$ is the amount of expansion (mm), $\Delta w$ is the water content increment. $a$, $b$ is the fitting parameter, and its value is related to the self-property and external conditions of the soil used. For the present experiment, it is the same soil, and the external load is the same, which is only related to the initial water content.

4. Conclusion
   (1)In the permeability test of remolded soil and undisturbed soil, with the increase of overburden load, the permeability coefficient decreases gradually; Due to its compact structure, undisturbed soil is not easy to penetrate; For remolded soil samples with different dry densities, the permeability coefficient decreases with increasing dry density; For remolded soil samples of different heights, the permeability coefficient gradually increases with the increase of height, and the faster the height increases, the faster the permeability coefficient changes. For remolded soil samples with different water contents, the permeability coefficient first decreases within a certain range with the increase of water content, and then gradually increases with the increase of water content, and the faster the water content increases, the faster the permeability coefficient increases.
   (2)In the expansive experiment, as the initial water content increases, the amount of expansion gradually decreases, and the expansion force also decreases; The larger the water content, the larger the expansion; because the initial water content is increased by increasing the amount of water during the test, and the moisturizing is extended for a long time, causing a part of the expansion force to be released in the form of the amount of expansion. The more the initial water content increases, the more the expansion force is released in the form of expansion, and the remaining expansion force is smaller.
   (3)In the expansion model experiment, with the increase of the number of openings, the expansion decreases in three stages: the water-adding stage, the normal expansion stage and the expansion stable stage. When the water is added to a certain extent, the expansion is stable, indicating that the soil sample no longer expands. At this time, the soil sample reaches the maximum expansion value. With the increase of water content, the initial expansion of soil samples with different pore numbers is different, and the final expansion amount shows a decreasing trend.

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