Experimental Study on Physical Properties of Octadecylamine Modified Expansive Soil

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Abstract. Taking weak expansive soil as the research object, octadecyl primary amine (octadecylamine) was mixed into remolded expansive soil as a water repellent, and modified samples with different octadecylamine content were configured. The water-repellent grade of the modified expansive soil was measured by the dripping water penetration time method, the boundary moisture content test of the modified expansive soil was carried out, and the change law of the liquid plastic limit of the modified expansive soil with different octadecylamine content was analyzed. The results show that with the increase of the octadecylamine content, the liquid limit of the expansive soil gradually decreases, the plastic limit gradually increases, and the plasticity index gradually decreases. The above research results can provide a test basis for the engineering application of modified expansive soils.

Keywords. Expansive soil, octadecylamine, water repellency, liquid and plastic limit.

1. Introduction
Expansive soil is a kind of clay with high dispersibility and high plasticity. Because it is rich in strong hydrophilic clay minerals such as montmorillonite, it is more specific than general hydrophilic soil [1], and its engineering properties, more complicated [2]. The repeated action of water causes rapid deterioration of the engineering properties of expansive soil [3]. The properties of expansive soils, such as water-absorbing expansion and water-loss shrinkage, are particularly likely to cause building cracks, slope instability, channel bridges and other structural damage, causing serious damage to the project in the expansive soil area for a long time, bringing huge safety hazards to the construction of the project, huge economic losses and casualties [4]. Geotechnical scholars at home and abroad use lime [5], cement [6], natural sand and gravel [7], blast furnace water slag [8] and other materials to improve expansive soil to solve the problem of expansive soil engineering. However, the current general measures only slightly improve the hydrophilic effect of expansive soil. If the expansive soil can be treated with technical means to make it water-repellent and applied in anti-seepage engineering, it will not only significantly enhance the anti-seepage effect of the project, but also solve the problem of expansive soil engineering.

The common ways to modify expansive soil mainly include physical modification [9], biological modification [10] and chemical modification [11]. Wang Baotian et al. [12] used CTMB modifiers to conduct water-repellent modification studies on natural expansive soils to study the changes in plasticity and expansibility. However, there are few studies on the basic physical properties of water-repellent expansive soils, so it is necessary to carry out the above research. In view of the above research, this article uses octadecylamine as the water repellent, configures expansive soil samples
with different octadecylamine content, and uses the drip penetration time measurement method to
determine the water repellency level of the modified expansive soil, and develops the corresponding
boundary water Rate tests, summarized the basic physical properties of modified expansive soils, and
provide experimental basis for solving expansive soil engineering problems.

2. Test Materials and Methods

2.1. Experiment Materials
The test soil was taken from a certain area of Kunming City, Yunnan Province. The soil was mainly
gray-white, dried and crushed and passed through a 2 mm sieve for use. The free expansion rate of the
soil is 52%. According to the national standard "Technical Code for Construction in Expansive Soil
Areas" (GB-50112-2013), it can be known that the soil sample is weakly expansive soil, and its basic
physical properties are shown in table 1. The BT-9300Z laser particle size distribution analyzer
produced by Dandong Baxter Instrument Co., Ltd. was used to determine the particle grading curve as
shown in figure 1. The mass of soil particles with a particle size of <0.002 mm, 0.002~0.02 mm and
0.02~2 mm accounted for respectively They were 6.72%, 56.32% and 36.96%. According to the
International Triangle Classification of Soil Texture, the test soil is silty loam.

The water repellent is octadecylamine (C\textsubscript{18}H\textsubscript{39}N), which is crushed to fine particles for later use.
Auxiliary materials and equipment include: deionized water, oven, beaker, plastic dropper, sprayer,
stopwatch, combined liquid-plastic limit tester, compactor, etc.

Table 1. Basic physical properties of expansive soil.

| Relative density | Dry density (g/cm\textsuperscript{3}) | Optimal moisture content (%) | Liquid limit (%) | Plastic limit (%) | Plasticity index | Free expansion rate (%) |
|------------------|---------------------------------|-----------------------------|-----------------|------------------|-----------------|------------------------|
| 2.71             | 1.56                            | 27.2                        | 63.5            | 30.8             | 32.7            | 52                     |

Figure 1. Gradation curve of expansive soil particle size.
2.2. Experiment Method

2.2.1. Drip Penetration Test. Stir the octadecylamine content of 0.2%, 0.3%, 0.5% and 0.8% with expansive soil and place them in an oven at 75°C. After drying for 8 hours, cool and take out to obtain 4 kinds of dry expansive soil with different water repellency levels. The drip penetration time method is used to determine the corresponding drip penetration time. The classification standard is shown in table 2.

Table 2. Severity ratings for soil water repellency by water drop penetration time (WDPT).

| Infiltration time /s | Water repellency |
|----------------------|------------------|
| <5                   | Wett able         |
| 5~60                 | Slight           |
| 60~600               | Moderate         |
| 600~3600             | Severe           |
| >3600                | Extreme          |

2.2.2. Boundary Moisture Content Tests. Octadecylamine only activates the surface of the expansive soil particles, making the expansive soil water repellent, and the internal structure has not changed. Specifically, in accordance with the "Geotechnical Test Method Standard" (GB/T50123-2019), five groups of water-repellent expansive soils with different octadecylamine content were tested for the critical moisture content.

3. Test Results and Analysis

3.1. Drip Penetration Test Results

Table 3 shows the drip penetration test results of modified expansive soil with different octadecylamine content. It can be seen from the table that when the content of octadecylamine is 0%~0.2%, the sample changes from non-water repellent to slightly water-repellent. This is because the content of octadecylamine is too low. Good coverage, so that the water repellent effect is not obvious; when the octadecylamine content increases to 0.3% and 0.5%, the water repellency level has reached medium and severe, and the sample has a certain water repellent effect; when the octadecylamine content is at 0.8%, the sample is extremely water repellent. Tests show that the water repellency of expansive soil increases with the increase of the mass fraction of octadecylamine. The larger the mass fraction of octadecylamine, the more fully contact with the expansive soil and the better the water repellency.

Table 3. Test results of water repellency grade of modified expansive soil.

| Octadecylamine content/% | 0    | 0.2  | 0.3  | 0.5  | 0.8  |
|--------------------------|------|------|------|------|------|
| Water repellency level   | Wettable | slight | medium | serious | extreme |

3.2. Boundary Moisture Content of Modified Expansive Soil

Figure 2 is a graph showing the relationship between liquid limit, plastic limit, plasticity index and octadecylamine content. It can be seen from figure 2(a) that the liquid limit of the water-repellent expansive soil decreases with the increase of the octadecylamine content, and the two are in a negative correlation. When the octadecylamine content increases from 0% to 0.8%, the liquid limit of the water-repellent expansive soil drops from 63.55% to 56.39%, which is a decrease of 7.16%. In contrast, the plastic limit of water-repellent expansive soil is positively correlated with the content of octadecylamine. When the content of octadecylamine is increased from 0% to 0.8%, the plastic limit of water-repellent expansive soil increases from 30.88% to 36.50%, increased by 5.62%. It can be seen from the linear relationship diagram of plasticity index in figure 2(b) that when the content of
octadecylamine increases from 0% to 0.8%, the plasticity index of water-repellent expansive soil decreases from 32.66 to 19.89, and water-repellent expansive soil shrinks compared with hydrophilic expansive soil, reduced by 39.10%. The plasticity index of soil can reflect the viscosity characteristics of soil to a certain extent. As the content of stearylamine increases, its plasticity also decreases. This is because as the content of octadecylamine increases, the water-repellent expansive soil surface has a smaller water binding force, and water is easily lost. When a certain amount of water is exceeded, the plasticity index decreases and tends to level off.

In the design code of highway subgrade, when the plasticity index of soil is greater than 26, it cannot be directly used for subgrade. For this test, when the octadecylamine content is 0.8%, its plasticity index is 19.89, which meets the engineering soil standard. To a certain extent, the octadecylamine water repellent not only makes the expansive soil with excellent hydrophilicity have high water repellency, and greatly improves its impermeability, but also improves the properties of the expansive soil, which can provide the design for the expansive soil area. It has a great engineering significance and economic benefits.

![Figure 2](image-url)

(a) Linear relationship diagram of liquid and plastic limits.  
(b) Linear relationship diagram of plasticity index.

**Figure 2.** Test result of limit moisture content.

### 4. Conclusions
1) The octadecylamine water repellent makes the expansive soil water repellent, and the water repellency level of the expansive soil increases with the increase of the octadecylamine content. When the content of octadecylamine is 0.8%, the water repellency level is extremely high, and the optimal water repellency effect can be achieved.

2) As the content of octadecylamine increases, the plastic limit of the water-repellent expansive soil gradually increases, and eventually tends to be flat. The liquid limit and plasticity index gradually decrease, and eventually tend to be flat. When the octadecylamine content is 0.8%, its plastic limit index is 19.89, which meets the engineering soil standard.

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