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The Influence of Alternate Dry-wet Effect on the Strength Characteristic of Expansive Soil

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ABSTRACT
The direct shear test was carried out to study the effect of the wet-dry cycle on the improved expansive soil that is mixed with lime and sand. The results showed that the age has a great impact on the shear strength of improved expansive soil, and found that improved expansive soil shear strength reduced with the increase of wet and dry cycles.

Key words **–** Improved expansive soil; drying and watering cycle; age; shear strength

I. INTRODUCTION

Expansive soil contained more hydrophilic clay minerals content, has the swell and engineering properties of water shrinkage. Expansive soil subgrade in highway engineering must be ameliorated to prevent the expansive soil under the condition of dry-wet cycle causing the damage of pavement. At present, the expansive soil is improved by lime, sand and fly ash etc in China.

Research on mechanics characteristics and physical characteristics of lime improved expansive soil were conducted by Qi Yin[1] and Qiong Xia[2]. A large number of engineering practices, simultaneously, have proved that using lime improved expansive soil has a good effect. By the laboratory of green-sand improved expansive soil, Xin Zhang[3] discovered that the strength of the green-sand improved expansive soil mainly depends on the moisture content of sample and sand content..

From the angle of the increase of shear strength, the expansive soil with lime is more effective than mixed sand, cement, fly ash. But in construction, because lime particles are small, it is difficult for construction site to mix and control, and the environmental pollution is larger. Moreover, expansive soil improved by lime has poor water stability and timeliness [4]. A certain amount of sand, therefore, was mixed in lime improved expansive soil to improve the effect of construction in our research.

Xianjie Mu [5], Yihu Liu [6] and Yanlin Zhao [7] carried on in-depth research on the change of the strength characteristics of expansive soil under the dry-wet circulation. But the dry-wet circulation researches on the effects of improved expansive soil are rare. Through experiments on physical property indexes of lime improved expansive soil under dry-wet circulation, Rao [8] found in the role of dry-wet circulation, liquid limit, plastic limit of calcareous soil, clay content increase. Further study, however, that dry-wet circulation affects the shear

Table 1 Physical parameters of soil

natural water content（%）	free swelling ratio （%）	organic content （%）	liquid limit	plastic limit
45.7	76	4.6	52	24

Table 2 Expansion rate of soil

Type	Soil	4% gray +5% sand (without maintenance)	4% gray +5% sand (maintenance)	6% lime (without maintenance)	6% lime (without maintenance)
expansion rate	9.45	1.15	0.48	0.86	0.40

strength of improved expansive soil should be conducted. So based on the improved expansive soil mixed the mixture of sand and lime as an example, we studied the effect of the dry-wet circulation on improved expansive soil shear strength.

II. Testing program

Soil samples were taken from Suqian section of 344 provincial roads, ShuYang to Lianyungang, and basic parameters of the soil sample is in table 1.

The sand that maximum particle's diameter is 2.36mm is the natural sand. Using the soil mixed with 4% of lime and 5% of sand, mixed with 6% lime improved expansive soil as the research object, we studied the changes of the shear strength of the soil sample without maintenance and maintenance under dry-wet cycle 1, 3, 5, 7, 9 times. The process that soil samples is soaked for 24 hours with the load and dried to the original quality is a dry-wet circulation. Soil samples were sealed, and room temperature was 29 ± 2℃, and the curing time is 7 days. The temperature of water was 25±2℃, and the samples were soaked with the load.

All soil samples were compounded with the optimal moisture (as shown in figure 1), and then soil was pressed into the ring on the compaction degree of 96%. The soil samples were used to the swelling capacity test under load respectively. Expansion rate is shown in table 2.

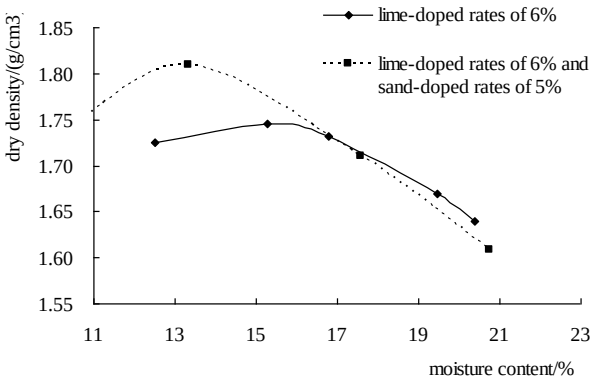

Fig. 1 water content and dry density curve

III. Mechanisms of strength formation

3.1 The chemical reaction between a small amount of activated silica and alumina in expansive soil and calcium hydroxide in lime generates insoluble in water of hydrated calcium silicate, and hydrated calcium aluminate, which makes soil particle bonded together, thus expansive soil strength and water resistance is improved.

3.2 Ion exchange: the Ca2+ and Mg 2+ in water and lime can make the electric double layer of expansive soil become thin. Accordingly, it increases the water stability of soil, reduces swelling, and increases the strength of the soil.

3.3 Carbonation: carbonization (as shown in the formula 3.1) that the products of calcium carbonate which solid-phase volume is bigger than calcium hydroxide make the structure of the expansive soil

more denser makes the strength of expansive soil enhanced.

$$Ca(OH)_2 + nH_20 + CO_2 \rightarrow CaCO_3 + (n+1)H_2O \quad (3.1)$$

3.4 Cementation: siliceous cements, carbonate minerals and sulfate minerals in the expansive soil make particles weld together. Consequently cementation makes the strength of expansive soil increased.

3.5 Gravel friction effect: frictional resistance between sand particles which are used to adjust the structure of expansive soil to reduce the sensitivity of the moisture content can improve the shear strength of expansive soil and reach the standard of soil roadbed road.

IV. Test Results and Analysis

4.1 Effect of age on the shear strength

The shear test about different age of samples was conducted in the strain controlled direct shear apparatus with different vertical to the load, and the shear velocity is 0.8mm/min.The age and the shear strength curve of the incorporation of 4% lime and 5% sand improved expansive soil is as shown in Figure 2.

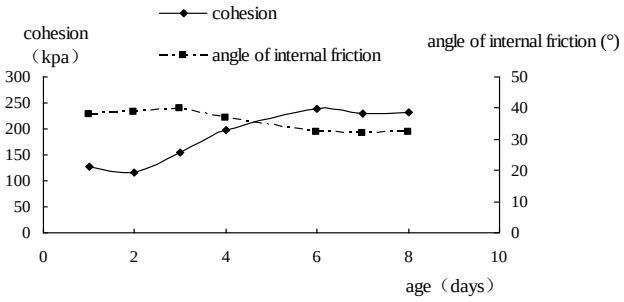

Fig. 2 Age and the shear strength curve

Fig. 3 curing soil sample

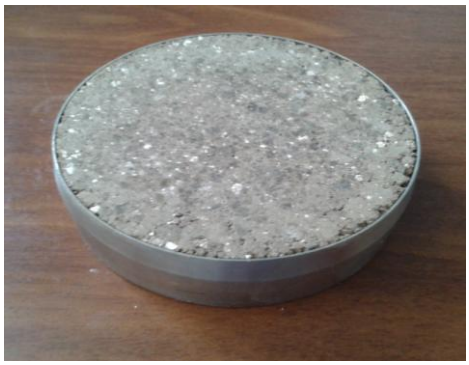

Fig. 4 Soil sample after the first of wet-dry cycle

From figure 2 we can see, with curing time increasing, internal friction angle of sand and lime improved expansive soil decreases, but the whole change is not obvious. The cohesion, however, increases dramatically. Maintenance for 6 days, shear strength tends to be stable. Possible reasons for this phenomenon are as follows: On the one hand, the chemical reaction between a diminutive amount of activated silica and alumina in expansive soil and calcium hydroxide in lime generates insoluble water of hydrated calcium silicate, and hydrated calcium aluminate, which makes soil particle bonded together, so expansive soil strength and water resistance is improved. On the other hand, ion exchange and carbonation are prevented by a protective film that formed by calcium carbonate, and small expansion of improved expansive soil will cause the internal friction angle decreases.

4.2 Effect of dry-wet cycle on the shear strength

After curing, the soil samples (as shown in the figure 3) are under dry-wet cycle, and after cycle the soil samples are as shown in figure 4. Soil samples in each group are done at least four groups of parallel test, we take the averages of the four sets of results that the test data could satisfy the requirement of precision as the final test results.

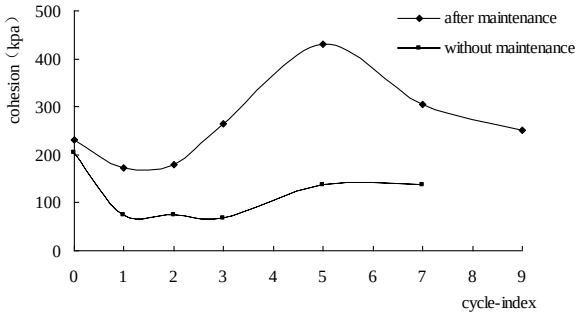

Fig. 5 curves of cycles and cohesion

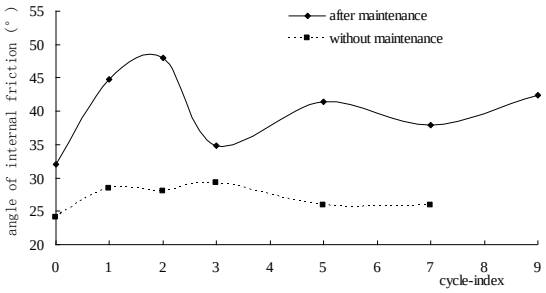

Fig. 6 curves of cycles and angle of internal friction

The curve of cyclic number and the shear strength is shown in Figure 5 and 6. From the figure 5, we can see that both cohesions have almost the same change trend, but the maintenance has good amplitude. For the first time, the cohesion of the soil samples decrease, then increase. After five times, decline again. Cementation between soil particles and the force of various physical - chemical bonding consist of cohesion, which is associated with the mineral composition and degree of compaction. After soaked, part of the cementing material is dissolved in water, and it makes the cohesive force of soil decreased, and soil structure is damaged at the same time. Once soaked again, soil particle fully contact with the water due to destruction of soil structure, result in lime carbonation intensified and cohesive force of soil sample increased. But as the cyclic number increase, more and more serious destruction to soil structure is taken, and cementation is weakened. Loose particles and lime carbonation weakened make the cohesive force decline.

The figure 6 shows that after a dry-wet circulation, internal friction angles of cured and without cured soil sample are enhanced, while both run in the opposite roughly after twice. After five times of dry-wet circulation, internal friction angles of cured soil change mitigated, and internal friction angle of without cured soil changes slightly. It is known that angle of internal friction reflects the friction properties of soil, which is thought to include two parts: the surface of the soil material friction and interlocking between particles. It is thought that after under dry-wet cycle, calcium carbonate generated by carbonation of lime has good effect on increasing the friction of soil particles, makes interlocking between particles sharpen, and makes internal friction angle increase in the early dry-wet circulation. As dry-wet circulation number increasing, the internal secondary fracture increase, soil structure broken, makes the internal friction angle fluctuate.

V. Conclusions

1 Studies have shown that age has greatly influenced on the shear strength of expansive soil modified by lime and sand. In engineering practice, in order to make sure the stabilization of the improved expansive soil strength, the lime improved expansive soil should be maintained at least 7 days.

2 Dry-wet circulation has large influence on shear strength of soil. After five times of dry-wet circulation, shear strength increases because of carbonation. With the increase of cycles, the shear strength of soil is in decay. Foundation drainage, therefore, should be considered in engineering practice where improved expansive soil is used.

3 The expansive soil improved by sand and lime can improve the swelling and strength, and it has the superiority in construction.

References

[1] Qi Yin, Jia Chen. Experimental study on the strength characteristics of lime treated expansive soils [J]. Urban Roads Bridges & Flood Control， 2008， (8):352-354, in Chinese

[2] Qiong Qi, Youhai Yang . Experimental Study of Improved Expansive Soil Filling with Lime[J]. Journal of Lanzhou Jiaotong University, 2009, 28[4]:30-34, in Chinese

[3] Xin Zhang, Shulin Sun etc. Laboratory test

study of properties of expansive soil improved by waste foundry sand[J]. Soil Mechanics, 2012, 33(2):209-212, in Chinese

[4] Jun Yang, Lei Tong, Guodong Zhang etc. Research on shear strength index of expansive soil modified by weathered sand[J]. Research of Soil and Water Conservation, 2013, 20(2):276-281, in Chinese

[5] Xianjie Mu, Xiaoping Zhang. Research on mechanical properties of expansive soil under wetting-drying cycle [J].Soil Mechanics, 2008, 28:580-583, in Chinese

[6] Yihu Liu, Guolin Yang, Xiangjing Huang. Experimental study on the failure mechanism of expansive soil roadbed under wetting-drying cycle[J]. Journal of China & Foreign Highway, 2006, 26(3):30-36, in Chinese

[7] Yanlin Zhao, Zhaotian Zeng, Haibo Lv. Wetting-Drying Cycle Influence on Expansive Soil Deformation [J]. Journal of Guilin Institute of Technology, 2009, 24(4):470-474, in Chinese

[8] Rao S M，Reddy BVV，Muttharam M. Effect of Cyclic Wetting and Drying on the Index Properties of a Lime-Stabilized Expansive Soil［J］. Ground Improvement，2001，5(3) : 107--110．