ISSN: 2472-3703 DOI: 10.6911/WSRJ.202001_6(1).0027

Experimental Study on Shear Properties of Aeolian Soil under Freezing-Thawing Cycle

Zenghua Lin[1,*] and Guozhi Sun[2]

[1]University of science and Technology Liao Ning, the school of civil engineering. Anshan, China

[2]Liaoning Geological Exploration and Mining Group. Shenyang. China

Abstract

This paper aims to study the change law of freezing and thawing of aeolian soil, and then reveal the destructive properties of aeolian roadbed in seasonally frozen region. In this paper, the triaxial test on aeolian soil under freezing-thawing cycle is carried out to study the effect of different freezing-thawing cycles on the shear strength of aeolian soil. The study shows that with the increase of freezing-thawing cycles, the overall variation trend of shear properties of aeolian soil is first increased and then decreased. When surrounding rocks are 30KPa, 100KPa and 300KPa, the maximum shear strength is 371KPa, 487KPa and 721KPa, respectively. With the increase of freezing-thawing cycles, the cohesion of aeolian soil increases first and then decreases, and the internal friction angle decreases first and then increases. The test, which reveals the rule of shear strength variation of aeolian soil under freezing-thawing cycle, not only provides a certain theoretical basis for the corresponding study on aeolian soil roadbed destruction, but balso has important practical significance.

Keywords

Aeolian soil; freezing-thawing cycle; shear strength; experimental study.

1. INTRNDUCTION

Seasonally frozen regions are widely distributed in China. As winter temperature drops, water contained in soil will ice up, leading to frost heaving. The damage on road surface is even more severe when the partial freezing heaving occurs. When the frost heaving force exceeds the tensile strength of the road surface, road surface cracking will occur. With the rise of temperature in spring, the ice in the upper soil begins to melt, while the ice in the lower soil is still frozen, so the water content of the upper soil gradually increases and its strength decreases, resulting in thaw collapse. The evident damaging effect of frost heaving and thaw collapse on road surface has attracted widespread attention from experts [1-5], who have made great many analysis on frost heaving factors, the prediction through frost heaving model and the study on anti-frost heaving measures.

The study shows that the alternation between frost heaving and thaw collapse exterts a great influence on soil mass, which, to a large extent, determines the stability of soil mass. The stability of soil mass mainly depends on its shear strength, which is of great practical significance to this study of the shear strength of soil mass. The system of one-dimensional frost heaving test was employed by Hu kun [6] to conduct frost heaving test under free boundary, elastic constraint and rigid constraint conditions. Through which, the dynamic balance between soil mass' frost heaving force and quantity indicates that the frost heaving force decreases exponentially with the increase of the frost heaving quantity. Sheng Daichao [7] proposed a new frost heaving model based on the thermodynamics Clapeyron equation on ice lens growth,

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202001_6(1).0027

which can calculate both frost heaving amount and freezing depth through only a few simple soil parameters. Taking the aeolian soil in western Liaoning as the research object, Zhang Xiangdong [8] conducted the seismic subsidence test on aeolian soil under sinusoidal load of equal amplitude, and established the empirical formula of seismic subsidence coefficient. The study shows that the seismic subsidence coefficient increases with the rise of dynamic stress amplitude, water content and pore ratio. Liu Jiashun [9] studied the cumulative plastic deformation characteristics under cyclic load. Taking the aeolian soil from Sujiatun Village section under Harbin-Dalian high-speed railway as the research object, a series of consolidated undrained dynamic triaxial tests were conducted to study the cumulative plastic deformation law of soil samples with different moisture content, vibration frequency and compaction coefficient under different dynamic stress levels. Thermal elastic mechanics was used by Zhang Yuzhi [10] to derive 2-D numerical equation on the stress and deformation of frozen-soil roadbed and to establish a finite element of roadbed mechanics. The calculation results show that, as the frost heaving rate and freezing depth increase, so do the vertical displacement, lateral differential deformation, lateral displacement and tensile stress of the roadbed in seasonal frozen region. Yang Bo [11] made a statistical analysis on the freezing-thawing cycle, spatial distribution, the repeatability of freezing-thawing over the years, the location of non-uniform freezing-thawing and the quantity of freezing-thawing. Through which, a summary was made on the influence of roadbed freezing-thawing on the geometric change of traffic lines, serving as the basis for road freezing-damage repair in each freezing-thawing stage. Hu Yuan [12] studied the change of ground temperature around the gas pipeline and the law of frost heaving and thaw collapse in the cold region of the normal-speed railway, offering a clear direction for the design, construction and hazard control on the oil and gas pipeline in soil area.

The frost heaving of soil mass is affected by soil quality, freezing speed and temperature gradient, while the soil quality and temperature vary from regions to regions. Therefore, it is of great practical significance to study the law of frost heaving and thaw collapse change in the soil of different regions. We take the aeolian soil widely distributed in western Liaoning as the main object for this study. Through different times of indoor freezing-thawing cycles, the rule of shear strength change on aeolian soil is studied to reveal the failure mechanism of frost heaving and thaw collapse on aeolian soil.

2. TEST MATERIALS AND CONDITIONS

2.1. Soil Quality

To study the shear variation law of aeolian-soil roadbed packing under freezing-thawing cycle, aeolian soil in Zhangwu area of Fuxin City was selected for indoor screening and compaction tests, and the grading status of aeolian soil is shown in table 1.

Table 1. The physical properties of aeolian soil

Grain diameter (d>0.1mm)/%	Grain diameter (d=0.1~0.05mm)/%	Grain diameter (d<0.05mm)/%	Liquid limit/%	Plastic limit/%	Specific gravity
0.35	13.25	86.4	28.5	21.4	2.69

According to the classification method specified in Code for Design of Building Foundation (GB50007-2011), silty clay is selected as the test soil. Among all kinds of soil, silty clay is most likely to produce partial freezing heaving, and it also possess strong frost heaving properties. The maximum dry density of the soil obtained through light compaction test is 1.70g/cm3, and the corresponding optimum moisture content is 17.5%.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202001_6(1).0027

2.2. Test Conditions

In order to simulate the instantaneity of vehicle load, the triaxial shear test was conducted under unconsolidated and undrained test conditions. The confining pressures were 60kPa and 100kPa respectively, and the axial loading rate was 0.08mm/min. The freezing-thawing test specimen has no external water supply. According to the preliminary test, it takes 16 hours for the specimen to completely freeze at -10°C and 6 hours for it to completely melt at 15°C. Therefore, the 16-hour freezing temperature is -10°C for the test, and melting for 6 hours at 15°C is a freezing-thawing cycle. The freezing-thawing cycle of the test is 0, 1, 3, 5, 7 and 9 times respectively, and the average strength of each three speciman is obtained for comparative analysis.

2.3. Specimen Preparation

According to relevant provisions specified in the Standard for Soil Test Method (GB/T50123-2019), the air-dried soil sample shall be firstly screened through the sieve of 2mm aperture, before measuring its water content. And then, add water to the soil sample according to the results of calculation on optimal water content. Place the well-prepared wet soil in a moisturizing cylinder and let it stand for 24h. The soil samples shall be compacted in four layers, and the corresponding compaction height of each layer is 2.0cm. In order to ensure the uniformity of the compacted soil samples, vernier calipers are used to control the compaction height of each layer. After repeated tests, the dry density of the specimen can only reach 1.55g /cm3 and the moisture content is 17.5%.

3. TEST RESULT ANALYSIS

According to the requirements on the triaxial test in the Standard for Soil Test Method (GB/ T50123-2019), triaxial tests under different cycles and confining pressures are conducted, with the corresponding shear strength calculated for each three specimens. The variation of shear strength is shown in Figure 1, 2 and 3.

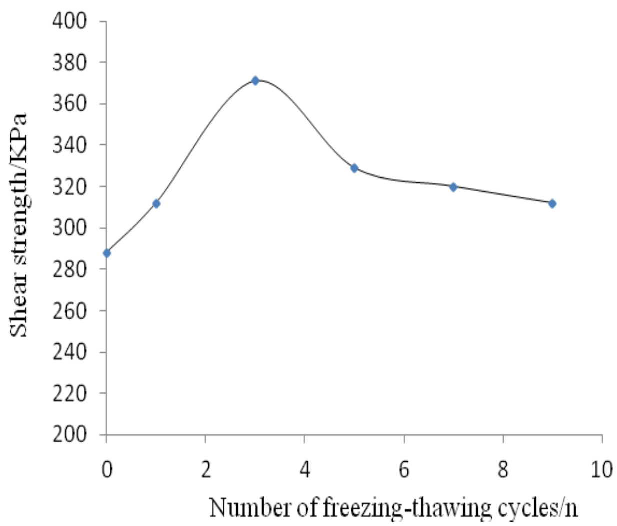

Figure 1. The shear strength of 60kpa surrounding rock under different freezing-thawing cycles

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202001_6(1).0027

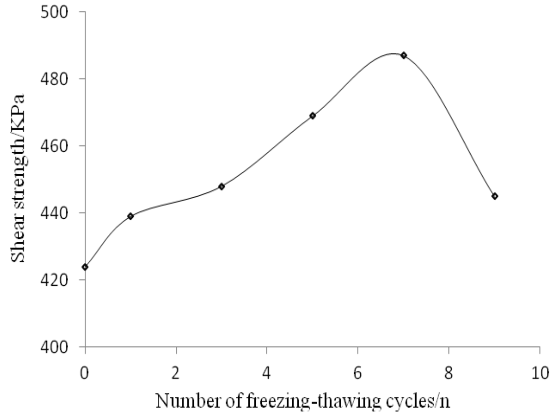

Figure 2. The shear strength of 100kpa surrounding rocks under different freezing-thawing cycles

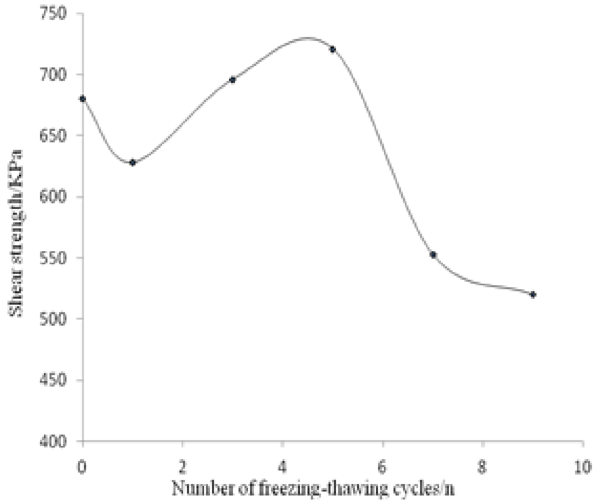

Figure 3. The shear strength of 300kpa surrounding rocks under different freezing-thawing cycles

The experimental results show that the soil shear strength increases with the rise of confining pressure. Under the same confining pressure, with the increasing times of freezing-thawing cycles, the shear strength of aeolian soil usually increases first and then decreases. When the surrounding rock is 60kpa, the shear strength of the aeolian soil after three freezing-thawing cycles reaches the maximum value of 371kpa. When the confining pressure is 100kpa, the shear strength of aeolian soil after 7 freezing-thawing cycles reaches the maximum value of 487KPa. When the surrounding rock is 300KPa, the shear strength of the aeolian soil after 5 cycles reaches the maximum value of 721KPa. As water in the specimen freezes, the water volume expands to increase the tightness between soil particles, and to a certain extend, the effective stress of the soil, thereby the shear strength of the soil is improved. Too many times of freezing-thawing cycles, however, will reduce the cohesive force between soil particles and cause some water loss, thereby increasing the soil void and eventually reducing the soil shear strength.

Combined with the triaxial test data, the mathematical expressions of the common tangent of three mohr stress circles are obtained through Excel's function of fitting curve, and through which, the cohesion c and internal friction angle φ are obtained. As the number of freezing-thawing cycles increases, the soil cohesion usually increases before decreases, and soil internal friction angle usually decreases before increases. The experiment shows that repeated freezing-thawing cycles will reduce the soil density and thus reduce the cohesive force, while repeated

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202001_6(1).0027

freezing-thawing cycles will increase the occlusal force between soil particles, thus increasing the internal friction angle to some extent.

4. CONCLUSIONS

1. Multiple freezing-thawing cycles will reduce soil compactness, thereby reducing the cohesive force. Generally, the soil cohesive force first increases and then decreases. Soil internal friction, on the contrary, usually decreases first and then increases, mainly because freezing-thawing cycle has increased the occlusal force between the soil particles.

2. Triaxial tests under different confining pressures and freezing-thawing cycles show that, with the increase of freezing-thawing cycles, soil shear strength increases first and then decreases, while the maximum shear strength of soil under different confining pressures is closely related to the cycle times. When the surrounding rock is 60kPa, the shear strength of the aeolian soil after three freezing-thawing cycles reaches the maximum value of 371kPa. When the confining pressure is 100kpa, the shear strength of aeolian soil after 7 freezing-thawing cycles reaches the maximum value of 487KPa. When the surrounding rock is 300KPa, the shear strength of the aeolian soil after 5 cycles reaches the maximum value of 721KPa.

ACKNOWLEDGEMENTS

Fund project: University youth fund: NO: 2015QN19.

REFERENCES

[1] S.G Zhang, Study on the Strength, Feezing-thawing and Fractal Properties of Aeolian Soil in Western Liaoning [J], Chinese Journal of Rock Mechanics and Engineering, 2004 (24):4261.

[2] J.N Yu, F.Y Tan.The Frost Heaving Deformation Analysis on the Freezing Process of Saturated Frozen Soil[J], Journal of Rock and Soil Mechanics, 2006, 27 (S1):203-206.

[3] H Bing, P He, C.S Yang. The Effect of Sodium Sulfate on Soil Frost Heaving under Open System [J], Journal of Glaciology and Geocryology, 2006 (01): 126 / 130.

[4] G.Y Zhu, Experimental Study on the Prevention and Control Measures against the Freezing Damage on Aeolian Soil Roadbed in Western Liaoning [D], Journal of Liaoning Technical University, 2007.

[5] Y Zhou, G.Q Zhou the Study on Generalized Quasi-static Model for the Growth of Soil Frost-heaving Lens[j], Journal of China Mining University, 2008 (03): 333-338.

[6] K Hu, G.Q Zhou. the Soil Frost-heaving Rule under Different Constraint Conditions [J], Journal of China Coal Society, 2011, 36(10):1653-1658.

[7] D.C Sheng, S Zhang. The Sensitivity Evaluation on Soil Frost Heaving [J], Journal of Rock Mechanics and Engineering, 2014,33(03):594-605.

[8] X.D Zhang, J.S Liu, Experimental Study on the Cumulative Plastic Deformation of Aeolian Soil under Cyclic Load [J], Journal of Highway Communication Technology, 2014,31(03): 18-25.

[9] X.D Zhang, J.S Liu. Experimental Study on Aeolian Soil's Seismic Subsidence Deformation [J], Chinese Journal of Soil Science, 2014,45(01):66-71.

[10] Y.Zi Zhang, Y.L Du. Study on the Freeze-thawing Deformation Law of High-speed Railway Subgrade in Seasonal Frozen Region [J], Journal of Rock Mechanics and Engineering, 2014,33(12):2546-2553.

[11] B Yang, The Frost Heaving Characteristics and Maintenance Measures of Ordinary-speed Railway Subgrade in Cold Region [J], Journal of Railway Construction, 2017 (07): 97 / 99.

[12] Y Hu, Z Xu, P.F Wang, Study on the Frost Heaving and Thaw Collapse of the Soil around the Gas Pipeline in Frozen Area [J], Journal of Engineering Geology, 2018,26 (04):1035-1042.