Effect of freezing temperature on unconfined compressive strength based on the freeze–thaw cycle

Mingxin Dai[1, a], Chongkang Zhang[1], Rui Wang[1] and Yulong He[2,*]

[1]School of Civil Engineering, Northest Forestry University, Harbin 150000, China;

[2]School of Civil Engineering, Jilin University, Changchun 130000, China.

[a] 1765001628 @qq.com

Abstract

In order to study the influence of different freezing temperatures on the unconfined compressive strength of polypropylene fiber soil under the action of freeze- thaw cycle. The effects of freezing temperature on the unconfined compressive strength of polypropylene fiber soils were analyzed by single factor test design. When the freezing temperature is -3, -5, -7, the unconfined compressive strength of the polypropylene fiber soil increases with the decrease of freezing temperature,so as to the fitted equation between freezing temperature and unconfined compressive strength of polypropylene fiber soil was established. Results show that decreasing the freezing temperature can reduce the effect of freeze-thaw cycle on the unconfined compressive strength of polypropylene fiber soil.

Keywords

Polypropylene fiber soil; Freezing temperature; Unconfined compressive strength; Single factor experiment; Freeze-thaw cycle.

1. Introduction

Heilongjiang is seasonally frozen region, The strength of subgrade soil in frozen region decreases greatly under freeze-thaw cycle's effect [1], Polypropylene fiber has good abrasive resistance, good corrosion resistance and low price[2],it can effectively enhance the strength of soil. It has been gradually applied to subgrade and soil engineering. Li guang xin [3] carried out the Triaxial test, found that the fiber can significantly increase soil cohesion so as to improve the shear strength of soil; The unconfined compressive strength of polyester fiber soft clay was tested by Kumar[4], and the results showed that the addition of fiber could improve the unconfined compressive strength of the sample; The experimental results of Zeng Jun[5] showed that the unconfined compressive strength of polypropylene fiber soil was higher than that of the plain soil. The unconfined compressive strength of polypropylene fiber soil increases with the increase of fiber content and fiber length. The study on the strength characteristics of the fiber soil under the freeze-thaw cycle (the Freeze-thaw cycle) has also achieved some results, the experiments of Han Chunpeng [6] show that with the increase of freezing and thawing times, the inner friction angle of the fiber soil is obviously enhanced by 1 times, and then the attenuation is found. Under freezing and thawing effect, The fiber has enhanced effect on the cohesive force of soil. Zhang Peng Far[7] etc by studying the mixing of polypropylene fiber and sisal fiber, it is found that the unconfined compressive strength of the soil can be increased to a certain extent. Thus it is proved that the fiber has a certain reinforcing effect on the structure. Schli [8] found that the peak stress and shear strength of polypropylene fiber reinforced lime soil were increased compared with ordinary lime soil. At present, the study on the unconfined strength variation of polypropylene fiber soil under freeze-thaw action is not cycle, Therefore, the polypropylene fiber soil was frozen under different temperature conditions, and the unconfined compressive strength test was carried out on the soil after freeze-thaw cycle. The effect of freezing temperature on the unconfined compressive strength of polypropylene fiber was studied.

2. Experiment Study

2.1 Test material

Test soil is derived from excavation foundation soil of new campus of Northeast Forestry University. The sampling depth was 1.5-1.8m, and the soil samples were yellow brown. According to test methods of soils for highway engineering [9](JTGE40-2007), The liquid plastic limit test of soil sample is carried out to determine the main basic physical indexes of soil sample.（Table 1）.

Table 1 Physical properties of test soil samples

Soil gravityG_S	Water contentω/%	Densityρ/(g · cm^{-3})	Plastic limitω_p/%	Liquid limitω_l/%	Plasticity indexI_P
2.67	4.2	1.68	25.07	38.53	13.46

The optimum moisture content Kop and the maximum dry density ρdmax were determined by the heavy compaction method. The test soil is passed through a 20 mm sieve, it is divided into 5 layers for compaction, and the number of hits on each floor is controlled 27 times according to the specifications, the test equipment is TDJ—V multi - function electric compaction instrument. Compacting experimental curve is Fig 1, the maximum dry density of soil samples is ρdmax = 1.76g / cm3 and the optimum moisture content is Kop = 13.76%.

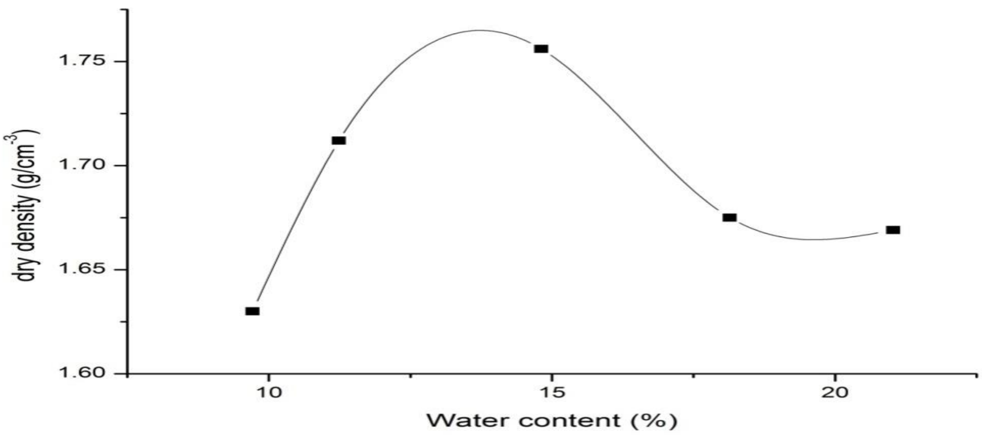


Fig.1 Compacting experimental curve

The fiber used in the test is a kind of polypropylene fiber made of Fuzhou bote polypropylene fiber Products Co., Ltd., the texture is soft and slippery, the color is white, and it is the long strip shaped fiber, the length of fiber used in this experiment is 9mm, it is main physical and mechanical parameters(table2).

Table 2 Physical and mechanical behaviors of propylene fiber

Types	Gravity	Elasticmodulus/MPa	Tensile strength/MPa	Melting point/℃	Diameter/μm	Limit tensile	Thermal conductivity
Bunchiness	0.91	3500	368	165	18~48	15%	Very low

2.2 Test methods

In this experiment, single factor analysis method was used to study the effect of this factor on unconfined compressive strength of soil by controlling single variable, and a single factor test with different freezing temperature as variable was designed. According to the experimental research of

Han Chunpeng [6],in this test the fiber length was 9 mm, the best combination plan of the fiber content was 3‰, according to He Yulong[10] and so on the conclusion with the freezing and thawing times increase, the unconfined compressive strength had certain enhancement, this test uses the freezing and thawing circulation times was once. The optimum water content of about 15% was tested by compaction test, using room temperature 15 ℃ as melting temperature, according to the average temperature of cold region-3℃, -5℃, -7℃ as a single factor variable of different freezing temperature, freezing time was 12h, and the melting time was 12h for unconfined compressive strength test, 3 parallel samples were designed to prevent errors in each group

2.3 Test material preparation

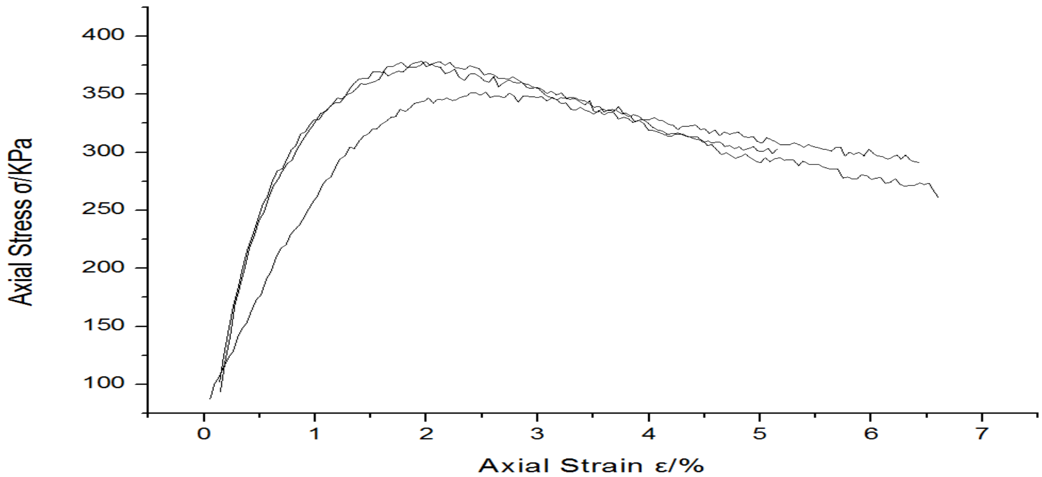
After the soil sample was dried and crushed, passing through the 5mm screen were retained, and the required water quantity was calculated according to the optimum moisture content of the soil body 15%, according to the fiber content of 3 per thousand, the 9mm polypropylene fiber should be called, and the soil sample, fiber and water will be evenly mixed, after mixing the soil was placed in sealed plastic bags 12h, the soil particles and water full role, The specimen is 96% of the compaction made of a height of 8.00cm, diameter of 3.81cm unconfirmed specimen, wrapped with plastic wrap to prevent the freeze-thaw cycle during the loss of water, were placed in different freezing temperature conditions , Frozen for 12h, the extraction was placed at 15 ℃ room temperature melting 12h. Unconfined compressive strength test was carried out by unconfined compressive strength equipment(LQ-2005) with the pressure rate of 1mm / min. Stress - strain curve of specimen is obtained(Table3).

Table3 unconfined compressive strength results

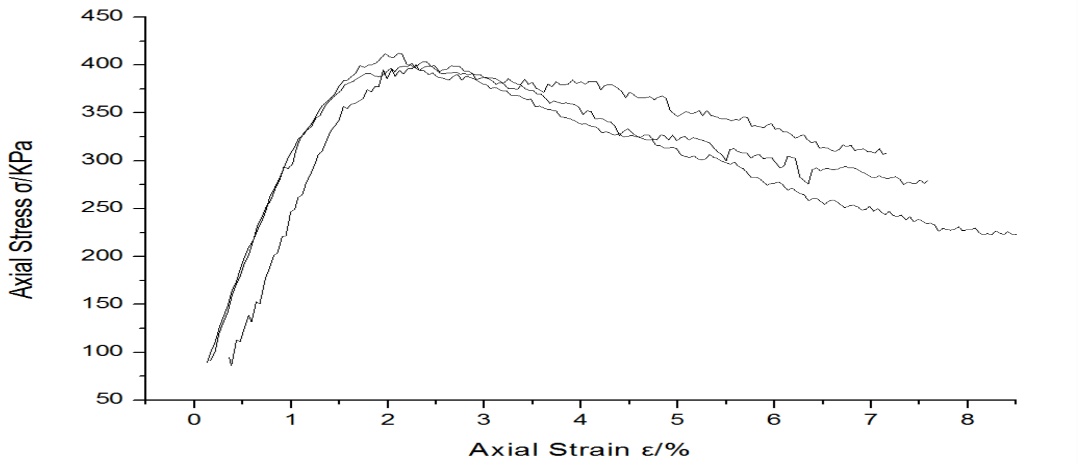
Temperature/℃	-3	-3	-3	-5	-5	-5	-7	-7	-7
Unconfined compressiveStrength/kPa	351.917	351.917	378.261	400.31	412.147	401.823	489.406	491.514	480.81

3. Analysis of test results

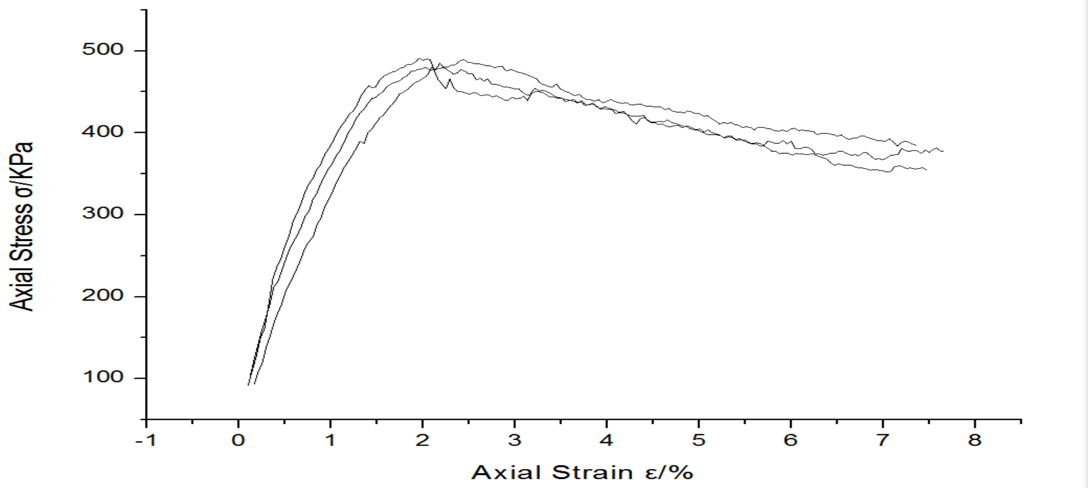
The stress - strain curves under different freezing temperatures are shown in the figure(Fig 2).



A. Stress-strain curve when temperature=-3℃



B. Stress-strain curve when temperature=-5℃



C. Stress-strain curve when temperature=-7℃

Fig.2 Stress-strain curve when temperature

It can be seen from the figure that the stress-strain curves of the three parallel specimens are basically the same, and the discreteness is very low, and the data is highly reliable. From the trend point of view, with the freezing temperature decreases, unconfined compressive strength is increasing

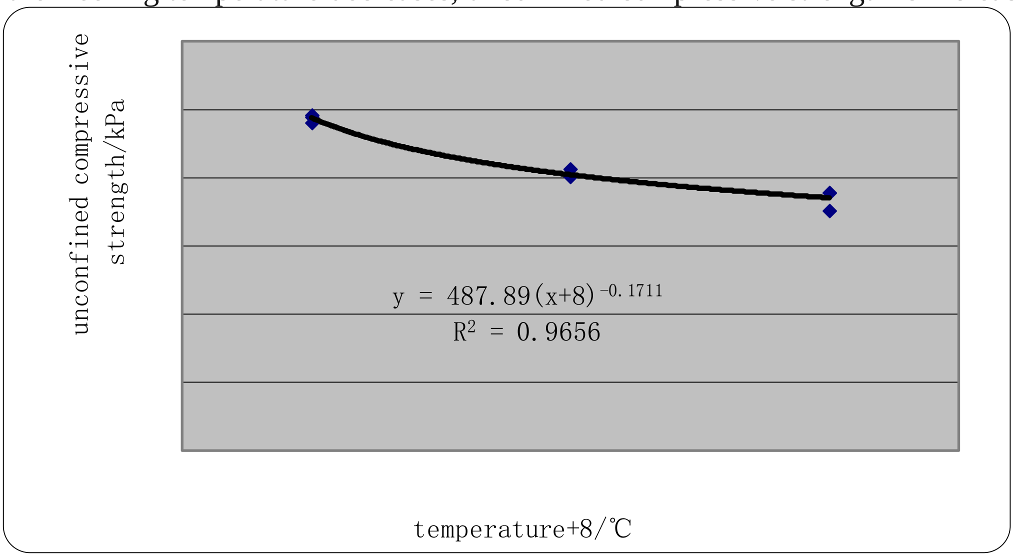


Fig 3 Freezing temperature content-Unconfined compressive strength curve

By fitting the data(Fig 3), the regression equation for the temperature variable is shown in Equation 1

$$y = 487.5(x + 8)^{-0.17} \quad (1)$$

x is freezing temperature/℃

The correlation coefficient of the simulation equation (R2=0.965) shows good data fitting result. It can be seen from the figure that as the freezing temperature continues to increase, the unconfined compressive strength of the soil is decreasing and the decreasing speed is slowing down, when the freezing temperature is low, the freezing speed of the soil is very fast, the moisture in the soil can not be moved and gathered, it has little effect on the pores. When the freezing temperature is high, the soil is frozen slowly, the water moves to the frozen zone, and a large amount of ice crystals are formed to destroy the pores. The condensation of water in the soil causes expansion and seriously affects the compressive strength of the soil. In order to study the influence of freezing temperature on unconfined compressive strength of polypropylene fiber soil, the significant level α=0.05, and the single factor analysis of variance was carried out. The results are shown in the table 4.

Table4 Variance analysis:One-way anova

A. Summary

Group	Observation number	Summation	Average	Variance
-3℃	3	1108.795	369.5983	234.5038
-5℃	3	1218.252	406.084	29.08165
-7℃	3	1461.73	487.2433	32.15175

B. Variance analysis

Difference source	SS	df	MS	F	P-value	Fcrit
Between groups	21758.39	2	10879.19	110.3601	1.85E-05	5.143253
Intragroup	591.4745	6	98.57908			
Total	22349.86	8				

It can be seen from Table A that when the freezing temperature is -7 ℃, the unconfined compressive strength of the specimen is the largest, the variance is small and the variation degree is very small. When the freezing temperature is -3 ℃, The mean compressive strength is the smallest, the variance is the largest and the variation is the largest. Table B shows the squares sum (SS), the degree of freedom (df), the mean square (MS), F value (F), significance probability (P), the critical value of F (Fcrit), The variance of the data originates from random errors in the group (the same freezing temperature) and random errors and systematic errors between groups (different freezing temperatures), it is a large probability event because of P-value=1.85E-05<0.05, Therefore, different freezing temperatures have a significant effect on the unconfined compressive strength of polypropylene fiber under freezing and thawing cycles,at the same time, F=110.3601>Fcrit=5.143253. Therefore, the F value of the data is outside the accepted domain of the F distribution and can not accept the original hypothesis. It can be concluded that the freezing temperature has a significant effect on the unconfined compressive strength of the fiber soil under the freeze-thaw cycle. This is consistent with the result of judging by probability.

4. Conclusion

The influence of freezing temperature on unconfined compressive strength was determined by single factor test.

(1)Under the action of freeze-thaw cycle, the unconfined compressive strength decreases with the freezing temperature increasing, and the unconfined compressive strength decreases rapidly between -7 ℃ and -5 ℃, and then the velocity begins to slow down, and the relationship can be fitted into a power-exponent function for analysis.

(2) Through the single factor analysis of variance, we get the significant level for α =0.05, P-value=1.85E-05< alpha, F>, Fcrit, which shows that the level of significance is very high, and the influence of freezing temperature on the polypropylene fiber soil is remarkable.

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