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Laboratory experimental study on improvement of silty soil lime and basalt fiber in Hangjiahu

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Abstract: There is a large amount of silty soil on the surface of Jiangsu and Zhejiang regions, which is not suitable for direct subgrade. After excavation, a large amount of abandoned soil will cause environmental pollution, occupy urban space, and even cause serious secondary disasters such as landslide and debris flow. Based on the improvement mechanism of silty soil, lime and fiber were added to the silty soil, and the improvement effect of the silty soil was studied by test method. The test results show that when the lime content is 4% and the basalt fiber content is 0.3%, the improvement effect of the lime - basalt fiber modified soil can meet the basic requirements of all grade road subgrade filling soil, and the splitting strength enhancement effect is significant.

Keywords: Mucky soil; Basalt fiber; Subgrade filling; Soil improvement.

1. Introduction

During the past 13th Five-Year Plan period, the scale of transportation infrastructure and urban construction has developed rapidly. Every year, the waste soil generated by engineering construction amounts to hundreds of millions of cubic meters, occupying a large amount of land resources for fixed consumption, and even causing environmental pollution. In addition, in the traffic planning of the 14th Five-Year Plan, the volume and investment of traffic engineering construction are also increasing. It is expected that a large amount of waste soil will be produced. The waste earth produced in Hangjiahu plain is mainly silts soil. In view of this, lime basalt fiber is used to improve silty soil and fill roadbed, which can not only solve the problem that a lot of abandoned earthwork in Zhejiang area cannot be disposed of, but also save roadbed earthwork. The research has certain economic and environmental benefits, which is in line with the requirements of economic development and ecological civilization construction in the 14th Five-Year Plan.

2. Improvement mechanism of lime-basalt fiber

The technology of lime improvement is the ion exchange between high price calcium ions in lime and low-price cations on the surface of soil particles, thus enhancing the mutual attraction and friction between soil particles. At the same time, the cementation between lime and soil particles forms a stronger cementing substance inside the soil, which effectively improves the bonding effect between soil particles and ultimately effectively improves the poor performance of silty soil. Fiber reinforcement technology is used to strengthen and improve soil by the friction resistance or bite force between fiber and soil particles. The calcareous soil aggregates adhere to the fiber surface, and the reaction products fill the soil crevices to squeeze the fiber. Thus, the interlocking action between reinforcement and soil interface is greatly strengthened and the friction coefficient between interface is increased.

3. Test scheme

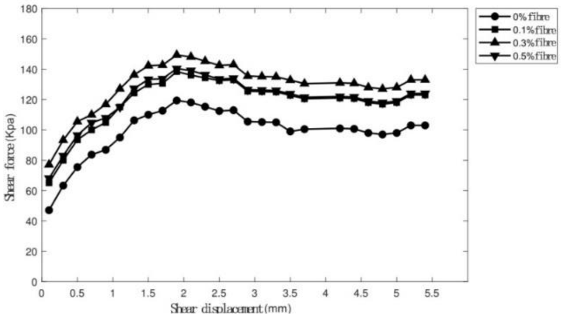
In order to study the strength characteristics of silty soil improved by lime and basalt fiber and determine the best content of basalt fiber which can meet the design specification of subgrade. According to "Code for Design of Highway Subgrade" JTGD30-2015, the minimum lime content that meets the requirement of subgrade construction strength is 6%, and the strength of silt improved soil with 4% lime content is somewhat different from that with 6% lime content. Therefore, in this experiment, silt improved soil with 4% lime content and different basalt fiber content is used to test the reinforcement effect of basalt fiber on soil. According to the basic physical properties of silty soil and related literature, the fiber content (the ratio of basalt fiber to dry soil mass of silty soil) is 0%, 0.1%, 0.3%, 0.5% respectively, and the lime content is 4%. Specific laboratory tests include: unconfined compressive strength test, direct shear test, and splitting strength test.

4. Experiment on improvement of silty soil by lime-basalt fiber

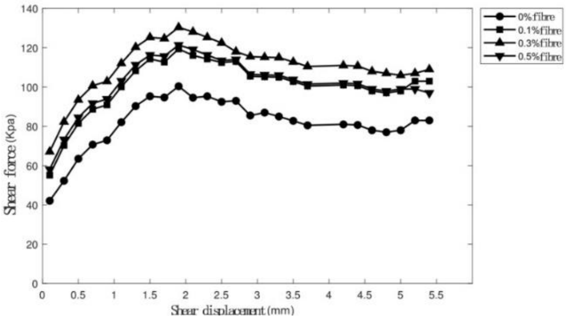
4.1. Direct shear test

In order to study the shear strength of silty soil improved by 0%, 0.1%, 0.3% and 0.5% basalt fiber lime at the optimum moisture content and 4% content, the test procedures are conducted in strict accordance with the Highway Geotechnical Test Regulations (JTG 3430-2020). The specific test results are shown in Figure 1 below.

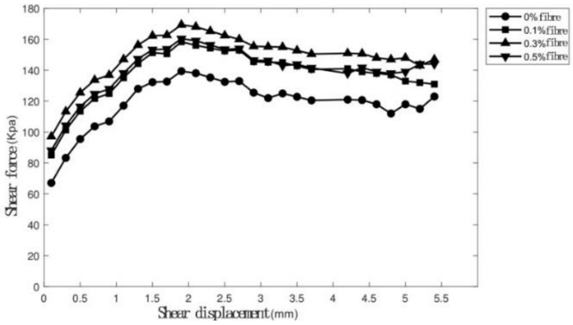
It can be seen from Figure 1 that the strength of lime-improved siltsoil jointly improved by basalt fiber increases first and then decreases with the increase of fiber content. The basalt fiber content at the peak is 0.3%, which is because the fibers are wrapped by cementing substances generated by physical and chemical reactions of lime-improved siltsoil. There is friction between these substances and fibers. With the increase of fiber content, the fibers in the soil sample interweave together to form fiber network, which improves the strength of the improved soil. When the fiber content is too high, the clumped fiber will affect the cementation of soil particles, so the strength of the improved soil decreases. Part of the fibers on the shear surface of the sample were not parallel to the shear direction, and there was an adhesion between these fibers and soil particles. Since the fibers used in this test were only 6mm, the interaction force was not particularly obvious. The analysis of the test results showed that when the lime content was 4% and the fiber content was 0.3%, the lime and fiber could improve the silty soil together better.



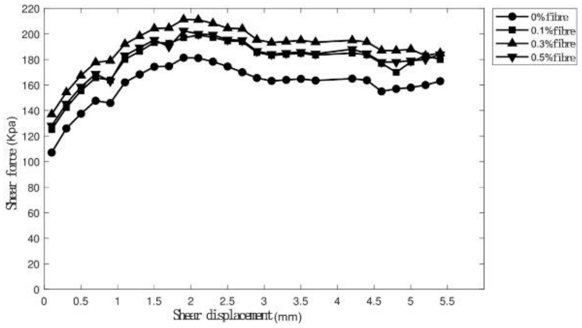
(a) Shear stress versus shear displacement curve(50KPa)



(b) Shear stress versus shear displacement curve (100KPa)



(c) Shear stress versus shear displacement curve (200KPa)



(d) Shear stress versus shear displacement curve (400KPa)

Figure 1. Shear stress versus shear displacement curve

4.2. Load bearing ratio (CBR) test

In order to study the load bearing ratio (CBR) of silt soil improved by 0%, 0.1%, 0.3% and 0.5% basalt fiber lime under the optimal water content and 4% lime content, the load bearing ratio (CBR) test was carried out in strict accordance with the Highway Geotechnical Test Procedures (JTG 3430 -- 2020). The specific test results are shown in Figure 2 below.

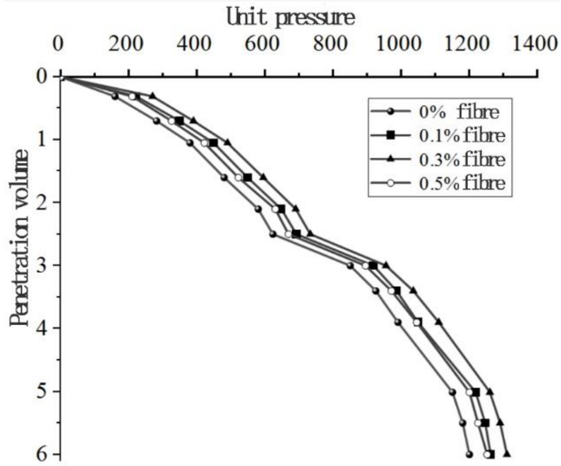


Figure 2. Plot of penetration curves at different basalt fibre doses

Table 1. CBR values for lime amended and basalt fibre amended silty soils

Test number	Fiber content/%	CBR value /%	Suitable subgrade position
1	0	7.2	All kinds of grade highway bed, embankment
2	0.1	7.6	All kinds of grade highway bed, embankment
3	0.3	8.3	Subgrade of various grades of highway
4	0.5	7.5	All kinds of grade highway bed, embankment

As can be seen from Figure 2 and Table 1, when the modified soil with 0% basalt fiber content is tested, the CBR value is low, but the distance to meet the normal design requirements is relatively close. When the basalt fiber content is increased, the CBR value is increased. When the basalt fiber content is 0.3%, the CBR value reaches the peak, and the subsequent increase of basalt fiber content decreases the CBR value. The reason for this rule is that when the basalt fiber content is small, the distribution is more dispersed, which can improve the soil integrity and the CBR value. When the basalt fiber content exceeds the maximum, the basalt in the soil body is easy to concentrate, thus reducing the soil cohesiveness and CBR value.

4.3. Unconfined compressive strength test

In order to study the unconfined compressive strength of silty soil improved with 0%, 0.1%, 0.3% and 0.5% basalt fiber lime content under the optimal water content and 4% lime content, the test procedure is carried out in strict accordance with the Highway Geotechnical Test Regulations (JTG 3430-2020). Specific test results are shown in Figure 3 and Figure 4:

It can be seen from Figure 3 and 4 that, with the increase of fiber content, the compressive strength of lime and basalt fiber modified silt soil increases first and then decreases, and the content at the peak strength is 0.3%. This is because when the fiber content is small, the fiber is dispersed in the soil sample, and the friction force and bonding force between the fiber and the soil interface as well as the spatial constraint effect of the fiber on the soil limit the displacement of soil particles and improve the integrity and strength of the soil. When the fiber content exceeds the critical content, a large number of fibers interweave together, showing the phenomenon of "clanging", forming weak surfaces, resulting in the increase of weak surfaces, and the collapse of three-dimensional spatial structure system easily. The interlocking friction structure between soil particles becomes loose, so the compressive strength decreases. When the fiber content is 0.3%, lime and basalt fiber can improve the silty soil best. This is because after the fiber is added to the soil, it is just like adding many fine tendons to the soil, forming a stable three-dimensional spatial structure system inside the soil, which will bear part of the tensile stress and play the role of connecting the clay particles as a mutual bridge to strengthen the connection strength between the soil particles. In other words, the reinforcement of the fiber to the soil is volume reinforcement. Finally, the overall stability of the soil is enhanced. The improvement effect of 0.3% basalt fiber content is generally better than 0.5% basalt fiber content.

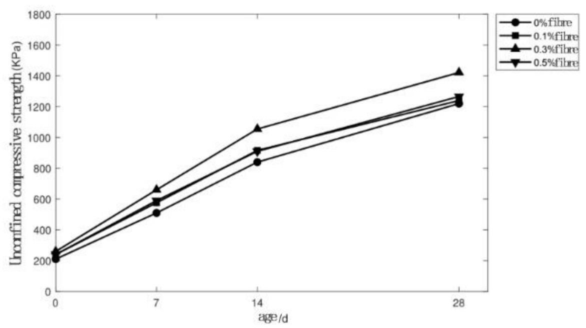


Figure 3. Curve of unconfined compressive strength versus age at maintenance

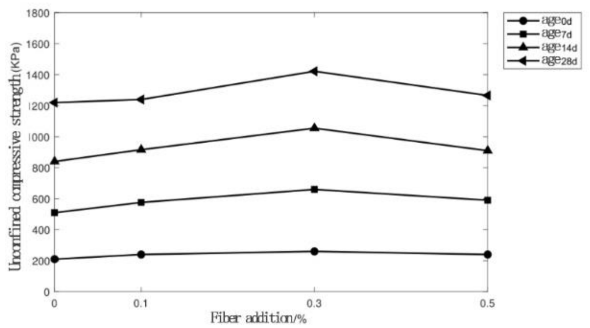


Figure 4. Curve of unconfined compressive strength versus lime addition

4.4. Splitting test

In order to study the splitting strength of silty soil improved with 0%, 0.1%, 0.3% and 0.5% basalt fiber lime content under the optimal water content and 4% lime content, splitting strength experiments were carried out in strict accordance with the Highway Geotechnical Test Procedures (JTG 3430 - - 2020). The test results are as follows:

From the analysis of Table 2 and Figure 5, it can be seen that with the increase of basalt fiber content, the splitting strength of lime-basalt fiber modified soil increases continuously. When the basalt fiber content is 0.3%, the splitting strength of lime-basalt fiber silt improved soil is higher. The splitting strength of lime-basalt fiber silt improved soil decreased. This is because the friction between basalt fiber and soil increases the shear strength of lime-basalt fiber silt improved soil. However, when basalt is excessive, it will condense into a group in the soil, forming a weak surface and reducing the splitting strength.

Table 2. Splitting strength at different ash blending levels

Basalt content (%)	Splitting strength (MPa)			
	0d	28d	90d	180d
0%	0.05	0.19	0.31	0.38
0.1%	0.07	0.21	0.35	0.42
0.3%	0.10	0.26	0.43	0.52
0.5%	0.08	0.23	0.38	0.46

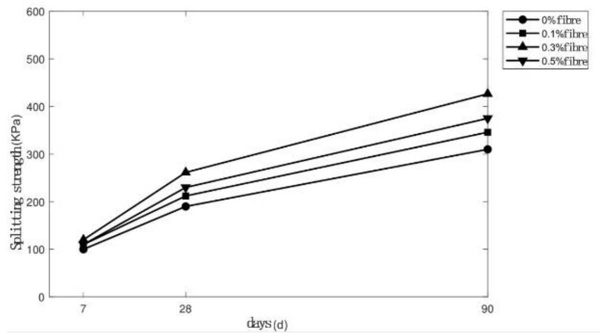


Figure 5. Variation of splitting strength with age for different lime amended soils

5. Conclusion

In this paper, the direct shear test, load-bearing ratio (CBR) test and unconfined compressive strength test were carried out by setting the lime content of 4% and basalt fiber content of 0, 0.1%, 0.3% and 0.5% respectively. After studying the test results, the following conclusions are drawn. When the silt soil is mixed with 4% lime and 0.3% basalt fiber, the shear strength, cbr value, unconfined compressive strength and anti-splitting strength of lime-basalt are the highest.

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