Chemistry in Building Materials
Volume 1 Issue 1 No. 4
Published Online July 1 2022

Effect of basalt fiber on compressive strength of cement soil

Jianlin Hu, Naifu Cui, Yudong Zhang
Hebei Institute of Architectural Engineering,Zhangjiakou City, Hebei Province, China

Abstract: As a high-quality reinforced material, basalt fiber has been widely concerned by scientific research workers. By changing the length (6mm,12mm,18mm,24mm,30mm) and amount of basalt fiber (0.3%,0.5%,0.7%,1%) and the proportion of cement in cement soil (10%,15%,20%,25%), make cubes of different ages(7d,14d,28d)and then conduct unconfined compression test. Effect on compressive strength of cement-soil with basalt fiber is researched. It is showed that the optimum mixing length of basalt fiber is 18mm and the optimum dosage range is 0.5%-0.7%.Basalt Fiber shows excellent performance on the early strength of cement soil and it has a good toughening effect.

Keywords: Basalt fiber, cement-soil, mechanical properties, effect research

1. Introduction

The coastal areas are the key implementation areas of China's economic development strategy and the densely populated areas and there is a large amount of soft soil in these areas. So cement mixing pile or jet grouting pile is often used in foundation treatment and foundation pit. Among the soil mixing pile, jet grouting pile and other construction techniques, the integrity of the pile is usually not good and is easily broken due to the strength of cement soil is not high or lack of toughness. Therefore, many scientific research workers begin to concern about the issue of how to improve the performance of cement soil and improve the strength of cement-soil mixing piles and pile into effect. Based on the soil constitutive model, an earlier study on fiber-reinforced soil was carried out by Jie Yuxin, Li Guangxin and a related calculation model was proposed[1].The application effect of fiber cement-soil in road base was studied by using polypropylene fiber and polyester fiber by Chen Shaojian [2].At the same time, The load test results of Maheshwari showed that fiber reinforcement can effectively improve the ultimate bearing capacity of soil and can reduce the settlement[3].Hao Wenxiu use the fly ash and glass fiber to improve the cement-soil, then analyzed the compression test results with the method of orthogonal test[4].Mohamed found that the shear strength of soil increased with the increase of fiber content, but the shear strength began to decline when the content reached 1%[5].In the aspect of improvement of basalt fiber to soil, Wang Jianye and Peng Liyun have studied the improvement effect of basalt fiber incorporation in silty soil in Daxing area of Beijing, and found that the silt shear strength, anti-permeability properties was improved[6]. For the improvement of basalt fiber on cement soil, the current research is not enough and the optimal ratio is not a more unified research results.

2. Experimental design

2.1 Test content

In the summary of existing research results of the premise, this paper intends to study the following aspects through the indoor test content:

(1) With the conducting of compressive test, the effects of different fiber incorporation length and fiber incorporation ratio on the mechanical properties of cement-soil are studied. Then the optimal incorporation length and the optimum incorporation ratio of basalt fiber are determined.

(2) The failure modes of fiber cement-soil and prime cement soil are studied,then the mechanism of fiber-modified cement-soil is analyzed.

In order to carry out a more accurate study of the above experimental content,the following research variables are made by accessing to the literature and drawing on some of the work done by researchers:The fiber length are 6mm, 12mm, 18mm, 24mm and 30mm and the content of fiber are 0.3%, 0.5%, 0.7% and 1%.Then the content of cement are 10%, 15%, 20% and 25%.

2.2 Examination program

In order to ensure the accuracy and maneuverability of the experiment, the experiment is divided into two stages: In the first stage, the optimal incorporation length of fiber was studied. In the cement-soil with different cement content, the same fiber weight (0.5%) and fiber length of 5 fibers are added. Three parallel tests are used in each case. 7 days, 14 days, plus prime cement soil test block as a contrast and a total of 144 blocks are made. The second stage, after determining the optimal fiber length, based on the change in fiber content, still using three groups of parallel test, with the same operation on the previous stage, curing age of 7 days, 14 days, 28 days and 180 blocks are made. Two stages of the total production of 324 blocks, then the unconfined compression test is conducted.

2.3 Experimental materials

Experiment material:(1) Soil material: the soil in Zhangjiakou area is sampled and the depth of sampling is 1m. (2) Cement: cement is produced by Xuanhua District Jinyu Cement corporation in Zhangjiakou City, labeling P.C32.5.(3)

Cut chopped basalt fiber is produced by a company in Nanjing.

Test equipment: (1) MQS-2 digital display material strength testing machine: maximum rated load 100KN, maximum moving distance 220mm, rated voltage 380V. Mainly used for compression test of cement soil block. (2)Automatic Mixer: mixing capacity 20L, power 3KW,Mainly used for fiber cement soil mixing. Other equipment: including ovens, electronic scales, test mode, mainly for the production of cement soil test block.

Table 1. Basic properties of soil indicators

Maximum dry density（g/cm^3）	Optimum moisture content（%）	Plastic limit （%）	Liquid limit （%）	Plasticity index	Engineering classification
1.68	14.8	15.625	28.75	13.485	Silty clay

Table 2. basal fiber basic indicators

Single fiber diameter(um)	Tensile strength (MPa)	Elastic Modulus(GPa)	Density(g/cm^3)	Ultimate elongation(%)	Operating temperature(℃)
14-16	4100-4800	91-120	2.65-2.8	2.7-3.3	-260-650

3. Analysis of results

3.1 Influence of fiber incorporation length on compression test results

In the first stage, the optimal incorporation length of the fiber is determined. When the fiber content is 0.5%, the fiber incorporation length is tested. The results of the compression test are as follows:

(1) The unconfined compressive test curve of cement soil under different fiber incorporation lengths (7d)are shown in Figure 1.

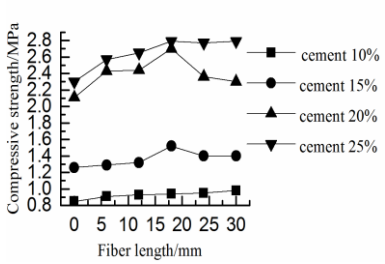

Figure 1. Compressive strength curves of different fiber length for 7 days with 0.5% content

It can be seen from the table that the compressive strength of fiber cement-soil blocks with different cement contents increases first and then decreases with the increase of fiber length under certain fiber content. The peak value appears at 18mm, and the change trend of 10% fiber cement soil strength with fiber length is not obvious. The reason is because the cement content is too little and the fiber can not be cemented with the cement, therefore the compressive strength growth is not high. When cement content is 20%, the fiber cement-soil compressive strength of the maximum increases by 28%,and when it is 25%, the highest compressive strength of fiber cement increases by 21%.

(2) The test curve of unconfined compressive strength of cement soil under different fiber incorporation lengths (14 d)are shown in Figure 2.

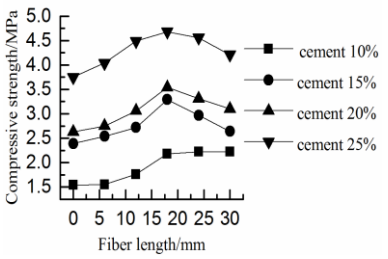

Figure 2. Compressive strength curves of different fiber length for 14 days with 0.5% content

When the age reached 14 days, the compressive strength of the test block changes more significantly, the same peak in the case of 18mm, and with the age growing, the strength of fiber cement increases significantly. The compressive strength of fiber cement soil is 44%, 24%, 25% and 21% higher than that of cement soil, respectively, when the content of cement is from small to large. It can be seen that under the condition of low cement content, the effect of fiber incorporation on the compressive strength of cement-soil is more obvious. After the increase of cement content, the increase range is stable at about 20%.

From the above results, the optimum length of fiber incorporation is determined to be 18mm, and it is found that the improvement effect of fiber on cement soil had a great relation with cement content and cement reaction time.

3.2 Influence of fiber incorporation ratio on compression test

After determining the optimal doping length of 18mm, in order to determine the optimal dosage of fiber, using 18mm as the determined fiber incorporation length and 7 days, 14 days and 28 days cement mortar samples are made. Unconfined compressive tests are carried out after the test piece reached the specified age. The test results are as follows:

(1) The compressive test curve of cement soil under different fiber contents (7d) are shown in the following Figure 3.

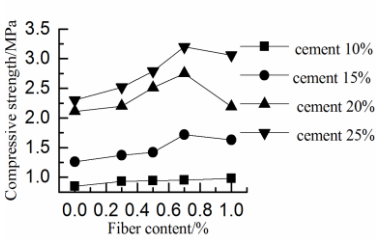

Figure 3. Compressive strength curves of different fiber content for 7 days with 18mm length

It can be seen from the chart that the unconfined compressive strength of the cement-soil block increases first and then decreases with the increase of the fiber content. The 7-day compressive strength curve showed a peak at 0.7% fiber mass fraction. But the age is too short, the optimal dosage of 0.7% can not be determined.

(2) The curve of unconfined compressive strength of cement soil under different fiber contents(14d) are shown in Figure 4.

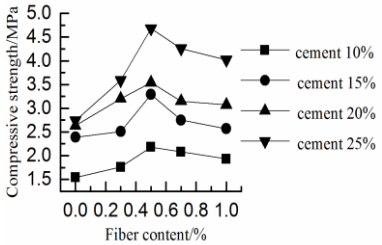

Figure 4. Compressive strength curves of different fiber content for 14 days with 18mm length

From the above table, it can be found that the 14-day compressive strength curve and the 7-day compressive strength curve of cement fiber with different fiber content are different under the condition of constant fiber length. Although the strength curve of this age test piece is more obvious, the peak appeared in the case of the fiber content of 0.5%, which is different from the best dosage of 7-day unconfined compressive strength curve. The reason is that the effect of fiber and cement tends to be complete with the increase of age. Therefore, under the condition of 0.5% fiber content, the peak value has appeared and the biggest increase ratio of the compressive strength of different cement content is 33%, 38%, 35%, 70%. It can be seen that when the fiber content is further increased, the role of excess fiber is not obvious due to the reaction is more complete, but led to the reducing of compressive strength of cement soil test block. And in this group of experiments, the increase is very large when the cement content is 25%.

(3) The curves of unconfined compressive strength of cement soil under different fiber contents (28d) are shown in Figure 5.

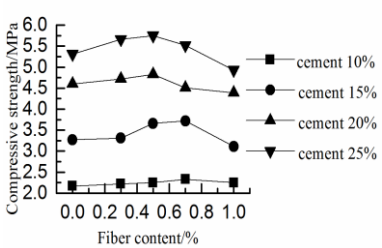

Figure 5. Compressive strength curves of different fiber content for 28days with 18mm length

Under the condition of fiber length of 18mm, the compressive strength curve of cement-soil test piece appeared two peaks at different fiber content. When the cement content was low, the peak value of fiber content appeared at 0.7%. When the amount is high, the peak appears at 0.5%. Except for the content of 10% , the increase of the compressive strength of the other three cement blocks was 13%, 5% and 4%, respectively. The increase range was little than that of 7-day and 14-day. This phenomenon indicates that the increase of fiber incorporation in the early strength of cement soil block is very obvious, but with the cement reaction tends to complete, although the compressive strength has improved, but not as early as obvious.

From the above data, it is found that the increase of the early compressive strength of cement is obvious, which is helpful to the safety and stability of the project. At the same time, the improvement effect of fiber on cement-soil mainly

depends on the degree of bond between fiber and cement, which shows the influence of cement content and age.

3.3 Mechanism analysis of fiber cement soil

By unconfined compressive strength test, the cement-soil mixed with fiber and cement-soil contrast, cement-soil in unconfined compression test achieves the ultimate compressive strength of brittle fracture and the hoop effect. When the cement-soil block is on the press, with the pressure increases, the role of the hoop is from the cement peeling or withdrawal from the force, less and less involved in the force of cement soil, and ultimately lead to brittle soil cement damage .

When the basalt fiber is mixed into the cement soil, with the compressive strength reaches the ultimate compressive strength in the unconfined compressive test, the first crack appears and develops into the big crack gradually, showing the whole force characteristic.

Compared with the cement-soil, the stress-strain of fiber-cement-soil is not rapid after reaching the limit state on the pressure testing machine, and the damage of the cement-soil is plastic.

Basalt fiber cement soil block will appear in the destruction of the short column. The main reason is the basalt fiber in the cement soil to play the role of rachel soil. In the crushed basalt fiber cement soil specimen, the basalt fiber in the compression process from the specimen was pulled out, cut off, which reflects the toughening effect of the basalt fiber, in the project can be remedied under sudden conditions to provide favorable support.

4. Conclusion and discussion

(1) The unconfined compressive strength test is carried out under different cement contents by changing the fiber incorporation length under the condition that the fiber incorporation ratio is fixed, and the optimal incorporation length is determined to be 18mm. In the experiment, block toughness is better.

(2) After determining the optimal incorporation length of fiber, the content of fiber is changed, and the unconfined compressive strength test is carried out on different cement content and different age. The results shows that the compressive strength of fiber cement depends on the degree of reaction between fiber and cement. Therefore, according to the length of cement, it can be mixed in 0.5%-0.7% fiber content.

(3) Through the analysis, it is found that the incorporation of fiber has an obvious effect on the early compressive strength of cement-soil, which is of great significance to the project with early strength. The improvement effect of fiber on cement soil is reflected in the improvement of the compressive strength of cement soil. What is more obvious is that the incorporation of fiber improves the toughness of cement soil and makes the work performance of cement soil more excellent. But the cement is still the main contributor to the compressive strength of cement soil, the role of fiber depends mainly on the degree of complete with the role of cement.

(4) The effect of fiber incorporation on the compressive strength and working performance of cement soil is mainly studied. The optimal length of fiber incorporation and the optimum dosage range are determined. In this paper, the durability test of cement soil is not enough and further study is needed by the researchers.

References

[1] JIE Yu-xin, LI Guang-xin. Study on calculation method of fiber reinforced soil. China Civil Engineering Journal, 1999,05:51-55.

[2] CHEN Shao-jian, WANG Dong-quan. Experimental study on fiber cement soil used in road subbase. Subgrade Engineering, 2009,02:143-144.

[3] MAHESHWARI K V, DESAI A K,SOLANKI C H. Performance of fiber reinforced clayey soil. The Electronic Journal of Geotechnical Engineering,2011,16:1067–1082.

[4] HAO Wen-xiu, SHEN Xiang-dong.Mechanical properties of glass fiber fly ash cement soil. Journal of Highway and Transportation Research and Development, 2012,03:12-16.

[5] MOHAMED,A E M K.Improvement of swelling clay properties using hay fibers. Construction and Building Materials, 2013,38:242–247.

[6] WANG Jian-ye, PENG Li-yun. Experimental study on properties of silt reinforced by basalt fiber. Journal of Beijing Jianzhu University, 2015,03:33-38.