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Unconfined Compressive Strength Test and Microstructure Analysis of Fibrous Soil-Cement

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Abstract. Adding fiber into soil-cement can improve its compressive and tensile strength. In engineering application, soil-cement can meet the requirements of mechanical properties and economic cost by adding a certain proportion of fiber, which has great significance for ensuring engineering quality, and reducing cost and increasing efficiency. In order to reflect the strength characteristics of soil-cement mixed with fiber and the performance of fiber constrained lateral deformation, the unconfined compressive strength test of soil-cement with fiber was studied in this paper. The results show that the addition of fiber can improve the mechanical properties of soil-cement, reduce the development of cracks and improve the ductility of soil-cement. Under the condition of the same incorporation ratio, the compressive strength of basalt fiber to soil-cement is improved more than that of polypropylene fiber. The test results can provide technical support and practical reference for long-term engineering safety.

Keywords. Cement soil, polypropylene fiber, basalt fiber

1. Introduction

The research shows that the compressive strength, shear strength and tensile strength of soil-cement can be outstanding improved by adding proper fiber into soil-cement [1-2]. At present, the main fiber added in soil-cement is glass fiber, polypropylene fiber and so on. Basalt fiber, as a new inorganic high-performance fiber material, not only has high mechanical strength, but also has excellent properties such as electrical insulation, environmentally friendly, corrosion resistance, high temperature resistance and so on [3-5]. It is a kind of green and environmental friendly material worthy of the name. It is a beneficial attempt to add basalt fiber and polypropylene fiber to cement soil [6-9]. The cement soil samples mixed with polypropylene fiber, basalt fiber comparative test are studied. The fibers used in the experiment are shown in figure 1. In order to reflect the mechanical characteristics of soil-cement mixed with fiber and the performance of fiber constrained lateral deformation, the unconfined compressive strength of two types

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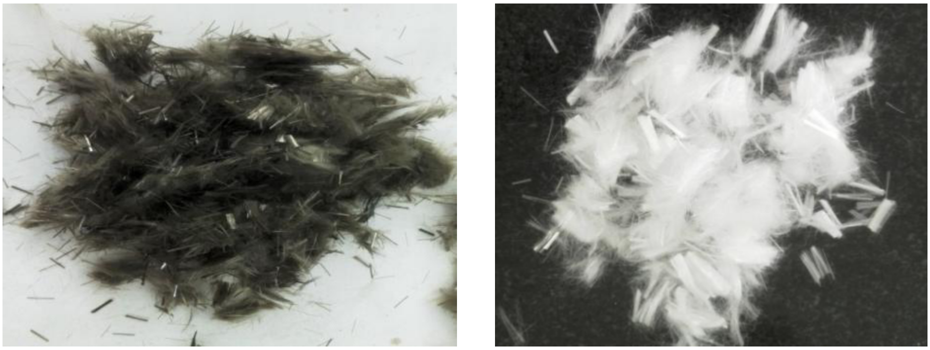
of soil-cement mixed fiber were studied in this paper.



(a) Basalt fiber (b) Polypropylene fiber

Figure 1. Two types of fiber were used in this experiment

2. Test Sample

The soil samples were taken from the east coast near a dyke of the OuJiang River in southeast Zhejiang Province. They are silty clay, light grayish yellow-gray, saturated, fluid plastic, and high compressibility. The natural density is 1900 kg/m^3, and the natural water content is 53%, and the liquid limit is 43%. The undisturbed soil is dried, ground and properly preserved after screening. When making soil-cement, the water-cement ratio is 0.9, P.O42.5 cement is used, cement incorporation ratio, fiber incorporation ratio is the percentage of cement quality, fiber quality and natural soil quality. Cement incorporation ratio, polypropylene fiber incorporation ratio and basalt fiber incorporation ratio were expressed as a_w, a_1 and a_2, respectively. The performance indexes of polypropylene fiber and basalt fiber are shown in table 1. The size of the cylindrical sample is 50mm×100 mm.

Table 1. Performance indicators of two types Fibers

Raw material composition	Monofilament diameter	Density	Average length	Tensile strength	Modulus of elasticity	Ultimate elongation
	mm	kg/m^3	mm	MPa	GPa	%
Polypropylene fiber	30	910	6	≥300	3.793	30~50
Basalt fiber	13	2 650	6	≥2 000	90~110	3.5

In order to be close to the environmental conditions of the deep underwater soil-cement mixing pile in seawater, seawater mixing was used in this test. The soil-cement samples were cured in seawater for 90 days, and then unconfined compression tests were carried out. Six samples were used in each group.

3. Results of Unconfined Test of Soil-cement

The unconfined strength test failure picture of plain cement soil with cement incorporation ratio of 18% is shown in figure 2 (a). It can be seen that when there is no fiber in soil-cement, brittle failure occurs in the test block, that is, vertical cracks appear with the increase of pressure, cracks are wide and long, and then the whole is crushed. The unconfined strength test damage of fibrous soil-cement with cement incorporation ratio of 18% and basalt fiber incorporation ratio of 0.2% is shown in figure 2(b). It can be seen that when the fiber cement soil is destroyed, the test block is basically intact and without peeling phenomenon, and the crack is narrow and fine, and the brittleness is obviously reduced.

(a) Cement-soil without fiber (b) Fibrous cement (a_2=0.2%)

Figure 2. Image of unconfined strength test failure of soil-cement (a_w=18%)

The results of unconfined compressive strength of soil-cement under different schemes are shown in table 2. Table 2 shows that adding fiber can improve the unconfined compressive strength of cement-treated soil. It can be also seen that with the increase of the fiber mixed with polypropylene fiber cement and basalt fiber, the cement-soil strength increasing amplitude will decrease, thus the fiber in the fiber cement-soil mixing ratio is not the more the better, but should be strength, economic and other aspects of the comprehensive comparison after the optimum adding amount. Table 2 and figure 3 indicate that the compressive strength of soil-cement can be slightly improved by adding fiber, however, the compressive strength of basalt fiber is higher than that of polypropylene fiber at the same incorporation ratio.

Table 2. Unconfined compressive strength of soil-cement at different schemes

Cement incorporation ratio	Element cement-soil	Fibrous cement/ MPa					
		a_1 / %			a_2 / %		
/ %	/ MPa	0.1	0.2	0.3	0.1	0.2	0.3
16	3.4	3.5	3.8	3.9	3.8	4	4.2
18	3.9	4	4.3	4.5	4.4	4.7	4.8

20	4.3	4.5	4.9	5.1	4.9	5.3	5.4
22	4.8	4.9	5.4	5.5	5.4	5.9	6

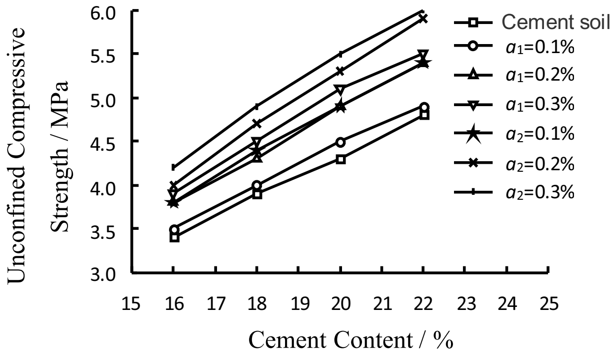


Figure 3. Unconfined compressive strength of soil-cement under different schemes

The stress-strain relationship of plain soil-cement (a_w=18%) and fiber soil-cement (a_w=18%) with basalt fiber incorporation ratio of 0.2% is shown in figure 4. It can be seen that the strain of soil-cement mixed with basalt fiber is about 3% when it reaches the peak stress, and that of plain soil-cement is about 1.5% under same condition. The residual strength of basalt fiber soil-cement is higher than that of plain soil-cement. Other soil-cement test blocks have similar characteristics, which indicate that with increase of fiber incorporation ratio, the strain of soil-cement increases obviously when the stress reaches peak, and the residual strength after failure also increases. It can be seen that add the fiber in soil can improve the ductility and mechanical properties of soil-cement, and can reduce the development of cracks.

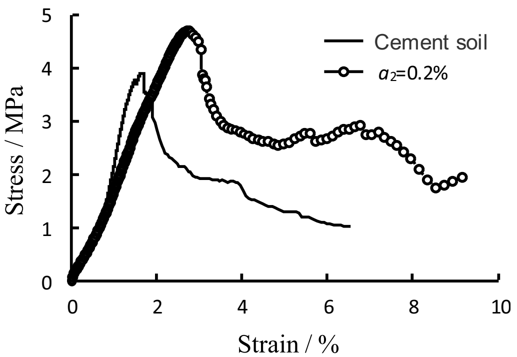
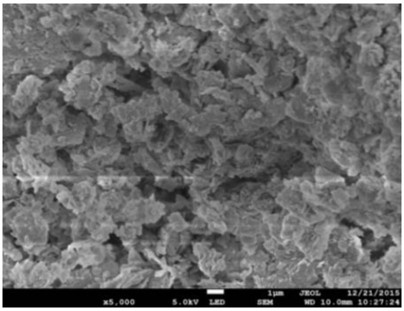
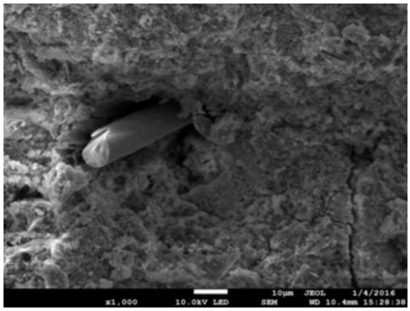


Figure 4. Stress-strain relationship of soil-cement

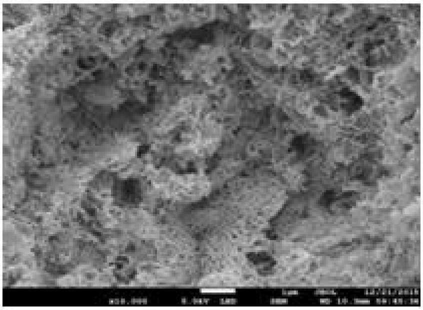
In order to further study the mechanical characteristics of plain soil-cement and fiber soil-cement, the samples of undisturbed soil-cement, the soil-cement after experimental damage mixed with basalt fiber and sheet hydrates formed after hydration of cement were collected and analyzed by Scanning Electron Microscopy (SEM), as shown in figure 5. The microstructure of the undisturbed soil is relatively large and loose, and the aggregates are directly connected by the combined water film, so the strength is relatively low. Cement-soil microstructure, compared with the original soil microstructure, cement-soil aggregate structure through cement hardening, cement and soil hydration products linked together, less porosity, soil becomes more dense, high connection strength, so cement-soil is called semi-rigid material. The soil-cement images with basalt fibers are failure samples. One end of basalt fiber is tightly wrapped by soil-cement, and the other end is the section of basalt fiber after being pulled off.



(a) Undisturbed soil-cement



(b) Basalt fiber in soil-cement



(c) Sheet hydrates formed after hydration of cement

Figure 5. Microstructure of undisturbed soil-cement and fibrous cement

4. Conclusion

Adding fiber in soil can improve the mechanical properties and ductility of soil-cement and can reduce the development of cracks. Furthermore, under the condition of the same incorporation ratio, the compressive strength of basalt fiber of soil-cement is significantly higher than that of polypropylene fiber, which indicates that addition of fiber has a significant effect on increasing toughness and reducing crack of soil-cement.

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