Test Research on the Strength of Ni-Fe Slag Powder Soil-cement at Early-ages

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Abstract. In order to study the effect of incorporation of Ni-Fe slag powder into soil-cement on its early strength, the unconfined compressive strength test and SEM test at 7d age and 28d age were conducted on the soil-cement with incorporation of 0%, 10%, 20%, 30% and 40% of Ni-Fe slag powder respectively. The test results showed that the soil-cement strength decreased with the increase in the content of Ni-Fe slag powder, especially at the age of 7d, the soil-cement strength decreased significantly, and the failure strain was also large, showing greater plasticity; at the age of 28 days, the reduction rate of soil-cement strength gradually decreased. Therefore, the contribution of Ni-Fe slag powder to the soil-cement strength was very small at the age of 7d, and it only gradually played its role at the age of 28d.

1. Introduction

Soil-cement refers to the civil engineering materials which are greatly improved in integrity, firmness and water stability after mixing cement, water, additives and other materials into the original soil or the soil sample after being pounded. With the rapid development of China's economy and urbanization process, the application of soil-cement has become more and more extensive by virtue of its excellent performance in engineering construction, especially the very mature application in foundation treatment, channel anti-seepage, foundation pit enclosure, soft soil reinforcement and other aspects. The extensive application of soil-cement in the engineering field has aroused the interest of many experts and scholars in the academic field, thus achieving fruitful research results over the years. Shenbaga r. k. anira et al. established the functional relationship between strength and age, cement consumption and fly ash consumption. Mostafa A.Ismail et al. studied the effect of different types of cement on the shear strength of solidified soil by triaxial test.

At present, great achievements have been made in the study of mineral admixture into soil-cement, but the research results mainly focus on the admixture of granulated blast furnace slag, fly ash, silica ash and etc. Ni-Fe slag is a kind of industrial waste slag discharged from nickel and stainless steel smelters. In this paper, the effect of Ni-Fe slag powder on the early strength of soil-cement was studied by incorporation of Ni-Fe slag powder into soil-cement.

2. Strength test

The materials used in this experiment were mainly cement, silty clay, nickel iron slag powder and purified water. The main physical and mechanical properties of soil are shown in Table 1. The cement is P•O42.5 ordinary Portland cement, and the compressive strength of cement at 3d and 7d was 25.7mpa and 46.3mpa respectively. The nickel iron slag powder was the S85-grade grey and white
nickel iron slag powder produced by Fujian Yuanxin Environmental Protection Technology Co., LTD, with its chemical composition shown in Table 1.

Table 1. Chemical composition of nickel iron slag powder(%)

| component | SiO$_2$ | Al$_2$O$_3$ | CaO | MgO | TiO$_2$ | MnO | Fe$_3$O$_4$ | SO$_3$ | f-CaO | LOI |
|-----------|---------|-------------|-----|-----|---------|-----|------------|-------|-------|-----|
| Ni-Fe slag powder | 35.8 | 21.4 | 29.2 | 9.46 | 0.78 | 0.57 | 1.33 | 0.1 | — | 2.43 |

The strength test of soil-cement was carried out by the method of unconfined compressive strength. The test block was a 70.7 x 70.7 x 70.7mm cube block, three parallel samples were made for each ratio of each age, and the average value of the sample was taken as the strength of sample. The test instrument was MTS Landmark 370.50 fatigue testing machine.

3. Results and analysis

3.1. Effect of Ni-Fe slag powder on strength

No lateral compressive strength was measured at 7d and 28d of Ni-Fe slag soil-cement, as shown in Table 2. Fig. 1 and Fig. 2 show the effect of Ni-Fe slag on soil-cement strength.

Table 2. Unconfined compressive strength (MPa)

| Content (%) | 0 | 10 | 20 | 30 | 40 |
|-------------|---|----|----|----|----|
| Ages(d) 7   | 1.08 | 0.86 | 0.79 | 0.57 | 0.43 |
| Ages(d) 28  | 1.74 | 1.69 | 1.55 | 1.40 | 1.01 |

Figure 1. Nickel iron slag powder content and strength of the relationship

Figure 2. Nickel iron slag powder content and intensity of the relationship between the rate of decline

It could be seen from Fig. 1 that, the strength of soil-cement added with Ni-Fe slag powder decreased at both the 7d and 28d ages with the increase in the content of Ni-Fe slag powder. By comparing the curves of soil-cement strength linked by different amounts of nickel and iron slag powder added at 7d and 28d, it could be seen that the overall slope of the curve at 7d age was greater than that at 28d age. Fig. 2 showed the reduction rate of soil-cement strength at different ages with the increase in the content of Ni-Fe slag powder relative to the base group of 0%. At the of 7d, the content of Ni-Fe slag powder was 10%, 20%, 30% and 40% respectively, and the strength decreased by 20.4%, 26.9%, 47.2% and 60.2% compared with the benchmark soil-cement. At the age of 28d, the strength...
decreased by 3.4%, 12%, 20% and 41.7%, respectively. Hence, at the age of 7 d, the role of Ni-Fe slag powder in cement-soil was very little, thereby making very small contribution to cement-soil strength, and its role was just like that of other admixture, namely, micro aggregate filling effect; simultaneously, it also hindered the formation of hydrated cement particles flocculation body due to being evenly distributed among the cement particles, thereby making the cement-soil strength in early stage decreased compared with the benchmark group. At the age of 28d, the decrease rate of soil-cement strength with different Ni-Fe slag powder decreased a lot compared with that at the 7d age, and when the content of Ni-Fe slag powder was 10%, the strength decreased by only 3.4% compared with the benchmark group. Therefore, it could be indicated that, by the age of 28d, the Ni-Fe slag powder mixed into soil-cement played a certain role in the strength of soil-cement, so that the droop rate of soil-cement strength mixed with Ni-Fe slag powder was gradually decreasing. This was mainly because the Ni-Fe slag powder was in the form of glass, and only when the cement clinker in the soil-cement was hydrated to a certain extent and an alkaline environment was formed in the soil-cement, the potential activity of Ni-Fe slag powder could be excited, thus generating the substances that exerted the increasing effect on the soil-cement strength. This was also the reason why the strength of soil-cement with Ni-Fe slag powder decreased greatly at the age of 7d, while the droop rate of strength decreased slowly at the age of 28d.

3.2. Deformation characteristics

3.2.1. Stress-strain curve

Fig.3 and Fig.4 show the stress-strain curves of soil-cement with different incorporation amounts of Ni-Fe slag powder at the ages of 7d and 28d respectively.

It can be seen from the figure that, when the content of Ni-Fe slag powder was 0% at the age of 7d, the stress-strain curve of soil-cement could present a relatively obvious three-stage curve, namely, the linear elastic stage, plastic yield stage and peak softening stage. As the content of Ni-Fe slag powder increased, its strain-softening property became less and less obvious. When the content of Ni-Fe slag powder was 40%, the stress-strain curve of soil-cement showed relatively similar properties to those of cohesive soil, and its trend was closer to that of strain hardening. Therefore, when the content of Ni-Fe slag powder was 40%, the soil-cement would become not very different from ordinary cohesive soil, its properties were closer to general cohesive soil, and its strength was also very low.

At the age of 28d, the stress-strain curves of cement-soil with different content of Ni-Fe slag showed obvious three-stage curves of strain softening, and the peak stress of the curves was more obvious. This showed that the Ni-Fe slag cement at the age of 28 days had a significant difference from the general cohesive soil, and the strength had been greatly improved.
3.2.2. Failure strain

Failure strain is one of the important indexes to measure the deformation characteristics of soil-cement. It could be seen from Table 3, Fig. 3 and Fig. 4 that, at the age of 7d, the failure strain of soil-cement was relatively large, and it increased with the increase in the amount of Ni-Fe slag powder, indicating that the plasticity characteristic of soil-cement was more significant at the early age, and the plastic deformation would be larger from the loading to the failure stage. At the age of 28d, the plastic deformation of soil-cement was generally less than that at the 7d age, and the failure strain of cement soil samples with 40% Ni-Fe slag powder had also decreased to 1.5%, showing that soil-cement was already of great strength at this time, and its failure was mainly brittle failure, as shown in Fig. 5.

![Figure 5. Specimen brittle shear failure](image)

4. Conclusion

1) At the age of 7d, the microstructure of Ni-Fe slag soil-cement is loose, there are many pores and cracks, and the incorporation of Ni-Fe slag powder will cause a great drop in the strength of soil-cement. The contribution of Ni-Fe slag powder to soil-cement is very small, which only plays the filling role of aggregate.

2) At the age of 28d, the microstructure of Ni-Fe slag soil-cement becomes denser and has better integrity, the strength reduction rate becomes smaller, and the brittle failure characteristics of cement-soil become very obvious.

3) The activity of Ni-Fe slag powder is low, especially at the early age, and the contribution to the strength of material is very small. At the age of 28d, its activity is excited and it starts to play a role on the material.

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