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Shear Strength and pH of Acidic Red Clay Amended with Oyster Shell Powder

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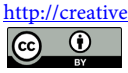

Abstract

In order to investigate the effect of oyster shell powder on the shear strength and pH value of acidic red clay, acidic red clay with pH value of 3.1 was used as the object of study, and oyster shell powder with particle sizes of <0.5 mm, 0.5 - 2 mm, and 2 - 5 mm were added into acidic red clay at the mixing amounts of 0%, 3%, 6%, and 9%, respectively, and the changes in shear strength and pH value were analyzed before and after the modification through the straight shear test and the pH value measurement, respectively. The test results show that oyster shell powder can effectively improve the soil shear performance index, and the soil cohesion reaches the maximum value and the internal friction angle appears to be the minimum value when the dosage of oyster shell powder is 6%. The dosage of oyster shells obviously enhances the pH value of the soil, and the increase of pH value gradually becomes slower with the increase of the dosage of oyster shells.

Subject Areas

Civil Engineering

Keywords

Oyster Shell Powder, Acidic Red Clay, Shear Strength, pH

1. Introduction

The area of acidic soils in the world is estimated to be about 40% to 50% of the potential cultivated area [1] [2], and in recent years, with the gradual increase in the impact of anthropogenic activities, especially in the high temperature and rainy climate of the south, the problem of soil acidification has become more and more serious. Among them, the increase in the concentration of dissolved heavy metals due to soil acidification [3] [4] and the loss of saline ions due to

leaching are extremely prominent in the pollution and quality of the soil environment. It affects the cultivation of crops, weakens the shear properties of the soil [5] [6] and erodes the foundations of buildings.

In response to these soil acidification problems, human research on soil amendments began in the late 19th century [7]. Current amendments for acidic soils are generally categorized as: inorganic amendments, organic amendments, biological amendments and composite amendments [8]. Inorganic lime for acidic soil improvement has the advantages of fast effect, obvious effect, etc., is the most traditional acidic soil conditioner in China.

Oyster shells are gradually being used for soil improvement because of their chemical similarity to limestone, and some research results have been obtained. Li Yanqiao *et al.* [9] used calcined oyster shell powder as the test material for a 1-year field tracking test on acidic soil planted with Koon Kee honeydew, and found an overall trend of first increasing and then decreasing soil pH and organic matter. Ruiqi Li [10] remediated lead-contaminated soil by adding modified poplar biochar composites with different ratios of oyster shells, and found that the addition of oyster shells modified biochar could effectively improve the pH value of soil, enhance the buffering capacity of soil to acid-base changes and the retention capacity of heavy metals. Huang Zhen [11] *et al.* carried out a series of expansion and contraction tests on expansive soils dosed with 0%, 3%, 6%, 9% and 12% of oyster shell powder respectively, as well as straight shear tests under dry and wet cyclic conditions, and analyzed the microstructural characteristics of expansive soils before and after the modification through SEM tests, and found that the oyster shell powder had a certain effect on the expansion and contraction characteristics of expansive soils and their strength characteristics. Chen Chuan [12] carried out cyclic loading of modified soil with oyster shells, and showed that as the particle size of oyster shells becomes larger, the modified expansive soil produces greater plastic deformation, and with the increase in the amount of oyster shell powder doping and the increase in particle size, the dynamic properties of the modified soil show a gradual decrease in the performance phase.

In view of this, oyster shell powder was studied as an amendment for acidic red clay. In order to investigate the improvement effect of biocalcium on the shear strength and chemical properties of acidic red clay, by carrying out straight shear research with different dosage, different particle size oyster shell powder improved acidic red clay shear strength index change rule, and using pH meter to determine the pH of acidic red clay before and after the improvement, to explore the effect of oyster shells on the improvement of acidic soil.

2. Test Method

2.1. Test Materials

The red clay soil of this test was taken from Lingchuan County, Guilin, Guangxi, at a depth of about 3.0 m. The original soil sample was reddish brown. The basic

physical properties of the red clay were measured through a series of indoor tests, as shown in Table 1.

Table 1. Soil Physical properties of red clay.

Specific Gravity	Maximum Dry Density (g/cm^3)	Optimum Moisture Content (%)	Natural Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)
2.72	1.78	18.44	27	53.4	28.5

In accordance with the provisions of the acidic soil pH less than 5.6, the experiment selected dilute sulfuric acid to adjust the pH value of the soil sample configuration of acidic red clay, dilute sulfuric acid diluted according to the proportion of the red clay after drying, the configuration of the acidic red clay soil samples with a pH of 3.1.

Oyster shells were purchased from Yangjiang, Guangdong Province, and crushed through 0.5 mm, 2 mm and 5 mm sieve by grinding bowl to obtain oyster shell powder with three particle sizes of less than 0.5 mm, 0.5 - 2 mm, and 2 - 5 mm, and the samples were in the form of grayish-white powder with the natural moisture content of 33%, and the samples were dried and sealed to keep in reserve. (See Figure 1 and Figure 2)

Figure 1. Oyster shells.

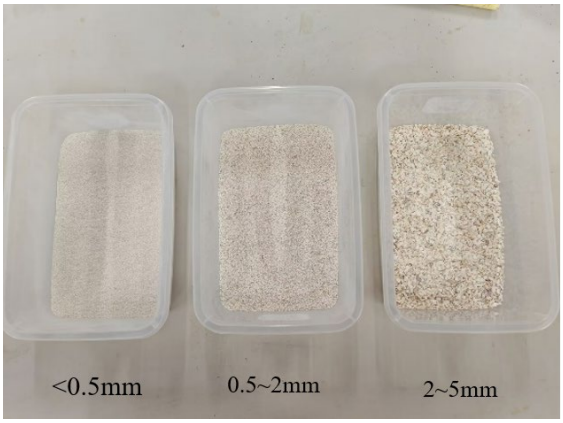

Figure 2. Oyster shell powder.

2.2. Straight Shear Test

The test was conducted by remodeling soil samples, after the retrieved red clay was naturally dried, it was ground and broken through a 2 mm sieve, and the oyster shells of three particle sizes were mixed with the acidic red clay with a moisture content of 18.44% after the configuration in the dosage of 0%, 3%, 6% and 9%, respectively. After one week of static pressure method, the soil samples were pressed into ring knife samples with dry density of 1.5 g/cm by hydraulic jack, the diameter of the ring knife was 61.8 mm, the height was 20 mm, and a total of 40 ring knife samples were prepared in the test. The prepared ring knife samples were subjected to fast shear test according to the test method of "Standard for Geotechnical Test Methods" [13] (GB/T 50123-2019), and the test was conducted by a quadruple straight shear apparatus with a shear rate of 0.8 mm/min and vertical loads of 100, 200, 300 and 400 kPa, respectively, in order to obtain the shear strength indexes of cohesion and internal friction angle. (See Figure 3 and Figure 4)

Figure 3. Quadruple straight shear.

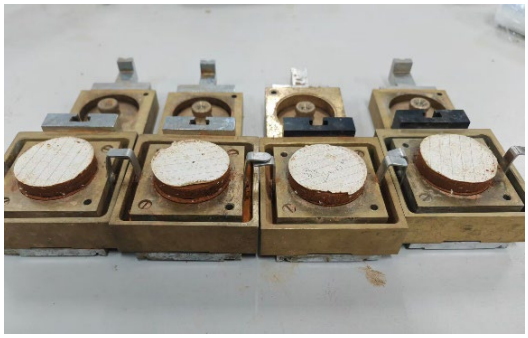

Figure 4. Ring cutter sample straight shear damage.

2.3. Determination of pH

The test was conducted using a pen pH meter to determine the acidity and alkalinity of the soil samples, which is shown in Figure 5. The configured soil was sealed and stored and maintained indoors in accordance with the relevant provisions of "Potentiometric Method for the Determination of Soil pH" [14] (HJ962-2018) to avoid its influence by acidic gases in the air and temperature

and humidity. After resting for one week and conducting straight shear test, the soil sample was weighed 10.0 g into a suitable container, and water was added to soak the soil sample according to the ratio of water-soil ratio of 2.5:1, and then the water-soil mixture was stirred thoroughly for 2 min using a stirring rod and then rested for 30 min.

Insert the electrode of the pH meter into the suspension of the specimen, and the electrode probe is not inserted into the liquid surface at a depth of 1/3 - 2/3, shake the specimen slightly, and record the pH value after the instrument reading stabilizes. Immediately after the completion of the test, wash with water and dry the electrode, and then proceed to the next test.

Figure 5. Pen pH meter.

3. Results and Analysis

3.1. Cohesion and Angle of Internal Friction

The data of straight shear test were processed to get the curves of **Figure 6** and **Figure 7** about the variation rules of cohesion and internal friction angle with content of oyster shell amended soil of different grain sizes. From the figure, it can be found that the cohesion and internal friction angle of acidic red clay both appear to change obviously with the increase of oyster shell content.

The cohesion of the amended soil with the same oyster shell particle size increased slowly and then decreased sharply with the increase of oyster shell content, while the cohesion of the amended soil with the same oyster shell content increased with the increase of oyster shell particle size, and the peak cohesion appeared at the oyster shell particle size of 2mm~5mm and the content of 6%, which was improved by 38.4% compared with the unamended acidic soil. On the contrary, the angle of internal friction of the amended soil under the same oyster shell particle size decreased slowly with the increase of oyster shell content, and the angle of internal friction of the amended soil under the same oyster shell content decreased with the increase of oyster shell size, and the minimum value of the angle of internal friction appeared in the oyster shell particle size of 2 - 5 mm and content of 6%, which was reduced by 48.3% compared to that of the unimproved acidic soil.

When oyster shells were mixed into the acidic red clay, the voids of the soil were filled with oyster shell particles, making the soil samples more compact; and oyster shells behaved as alkaline, which neutralized part of the acidity of the

soil, and in the process of acid and alkaline neutralization, a colloid was formed between the oyster shell particles and the soil particles, and the surface of the two kinds of particles became smoother, so that the cohesion of the improved soil was increased, and the angle of internal friction was reduced. When oyster shell mixing amount reaches 9%, oyster shell particles are too much, which destroys the structure of soil particles, and the acid-base neutralization efficiency is also greatly discounted, so that there are a lot of residual oyster shell particles that show the roughness of the soil, and therefore the cohesion of the improved soil becomes smaller, and the angle of internal friction becomes larger.

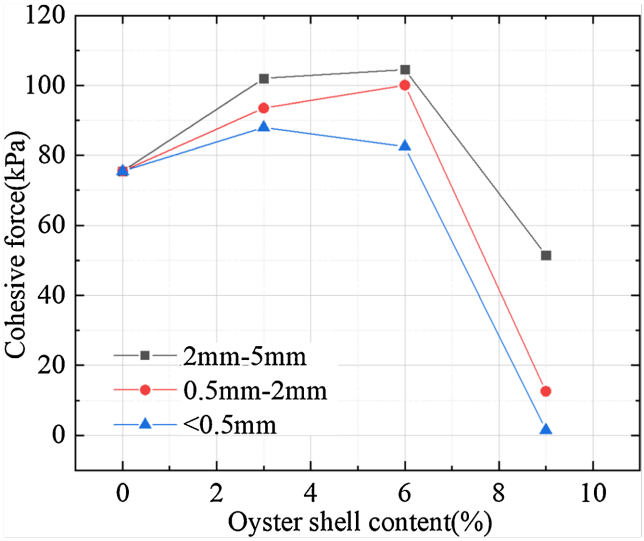

Figure 6. Variation of cohesion value with particle size and content.

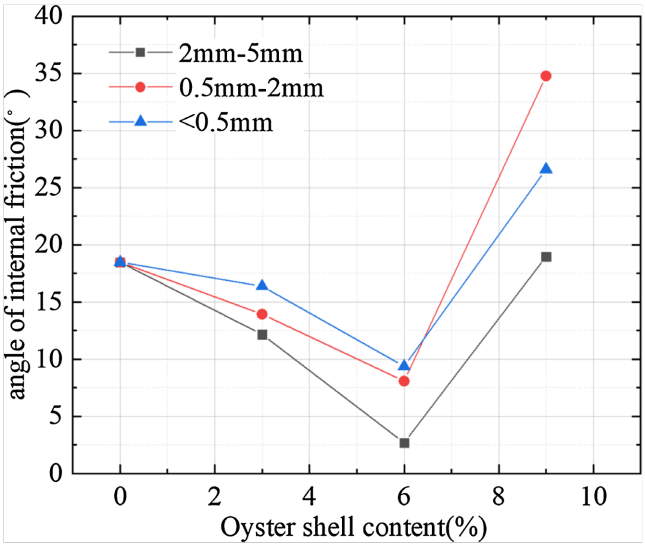

Figure 7. Variation of internal friction angle values with particle size and content.

3.2. Effect of Oyster Shells on the pH of Acidic Soils

Figure 8 shows the curves of oyster shell content versus pH of amended soil at

different particle sizes. It can be found in the figure that the pH of the amended soil increased with the increase of oyster shell content, but the trend of increase was slowing down. For any oyster shell particle size, the increase in soil pH was greatest when the oyster shell content was from 0% to 3%, with an average increase of 82.8%; the increase in soil pH was slower when the oyster shell content was from 6% to 9%, with an average increase of 6.5%. This indicates that oyster shells have a significant effect on neutralizing acidic soils, but there is an upper limit to this neutralizing ability.

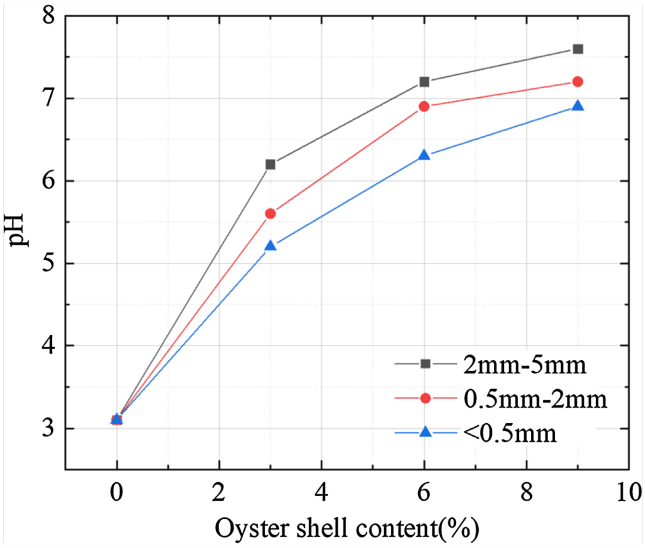

Figure 8. pH profiles for different oyster shell contents and particle sizes.

4. Conclusions

1) It was found that the acidic red clay soil was modified by oyster shell powder: The cohesion of the improved soil showed a tendency to increase and then decrease, and the peak value appeared at 6% of oyster shells; and the angle of internal friction of the improved soil showed a tendency of decreasing and then increasing, and the minimum value also appeared at 6% of oyster shells, so it is considered that 6% is the optimal content of oyster shells for the improvement of the acidic red clay soil.

2) Oyster shells can neutralise the general acidity of acid soils, thus raising the soil pH; as the oyster shell content increased, the soil pH increased, but the rate of increase gradually declined.

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Conflicts of Interest

The authors declare no conflicts of interest.

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