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Experimental Study on Shear Properties of Interface between Clay and Cement Paste

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Abstract. According to the typical clay in Changzhou, the shear properties of interface between cement paste and clay were studied through changing water content of clay and water cement ratio of cement paste. Rules of shear strength, internal friction angle and cohesion of contact surface between cement paste and clay changing with water content were researched. The results show that when the water cement ratio and clay moisture content remain unchanged, the shear stress increases with the increase of normal stress. After reaching a peak value, the shear stress begins to decrease. When water cement ratio and normal stress remain unchanged, the shear stress decreases with the increase of water content. When the water cement ratio is constant, the internal friction angle decreases with the increase of water content. When the water cement ratio is 0.4 and 0.45, the cohesion decreases with the increase of water content. When the water cement ratio is above 0.5, the cohesion increases first and then decreases with the water content. 17% is the optimum moisture content, at this time, the cohesion is the greatest.

1. Introduction

The problem of interaction from interface between soil and structure exists in geotechnical engineering universally such as the interactions between the soil and the foundation, piles, retaining structures, underground pipelines or anchors[1~5]. The water content of soil has a great influence on the working condition of the structure. Therefore, when analyzing the interaction between soil and structure, the characteristics of soil and structure should be considered. The principle of shear transfer at the interface between soil and structure should also be analyzed. Shear stress occurs at the interface between soil and structure when the soil and structure move relative to each other, because the deformation of soil and structure is quite different[6]. When the deformation of soil and structure is very different, the shear stress will be very large. In this way, the structure will be destroyed and the damage will be caused. Therefore, it is very important for analysing the structure deformation and ensuring engineering safety to study on the interaction of interface between soil and structure and to understand the shear mechanical properties of interfaces.

2. Research background of the subject

Changzhou is located in the Changjiang River Delta Plain and Taihu Lake alluvial plain in central Jiangsu Province, where hollow pipe pile foundation has been widely used in construction projects in recent years. Soil in Changzhou is usually unsaturated. The operation condition of the structure will

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affect the soil moisture content in practical engineering. It is necessary to carry out shear tests on the interface between cohesive soil and cement paste.

3. Design of the experiment

Physical properties were observed according to the typical clay in Changzhou. The indoor direct shear test of the contact surface between four groups of different water content of clay and four different kinds of water cement ratio of the cement paste was studied. Five normal stresses were considered in each group of tests. Three parallel samples were tested in each group.

Change the water content of clay. Clay with water content of 10%, 17%, 20% and 25% was prepared. Four kinds of cement pastes with different water-cement ratios of 0.4, 0.45, 0.5 and 0.55 were prepared. Five normal stresses of 50 kPa, 100 kPa, 200 kPa, 300 kPa and 400 kPa were considered in each group of tests. Record the temperature and humidity of the test. The test results were analyzed. Rules of shear strength, internal friction angle and cohesion of contact surface between cement paste and clay changing with water content were researched.

Typical clayey soils of Changzhou are used in this test. Put the soil sample outdoors and air-dry naturally. Take soil samples with particle size less than 0.074mm as test soil after crushing the air-dried soil[7]. Cement pastes with different water-cement ratios of 0.4, 0.45, 0.5 and 0.55 were made with sand with diameter of 1 mm, gravel with diameter of 2-5mm and No. 32.5 portland cement.

The 1cm high concrete block was made which using the lower box of the direct shearing instrument as the mould. Demoulding after 7 days of curing. Polishing around the test block until it can be put in the lower box (See Figure 1).

Figure 1. Cement pastes with different water-cement ratios

4. Collation and analysis of test data

(1)Drawing the relationship between shear stress and time which taking Shear Stress as horizontal coordinates and Time as vertical coordinates.

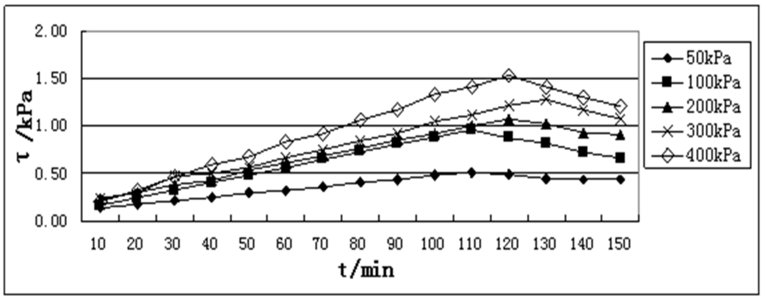

Figure 2. Typical variation curve between Shear Stress and Time

The typical curve is shown in Figure 2. The shear stress increases with time with the same moisture content and normal stress. After reaching a peak value, the shear stress begins to decrease.

When the normal stress is 50Kpa, 100Kpa, 200Kpa, 300Kpa and 400Kpa, the corresponding peak time is 105min, 107min, 115min, 105min and 115min, which is generally consistent. It can be seen that the time of peak value first increases and then decreases with pressure.

(2) When the water cement ratio and water content are constant, according to the shear strength(τ) corresponding to different normal stresses(σ), the relationship curves between σ and τ are drawn.

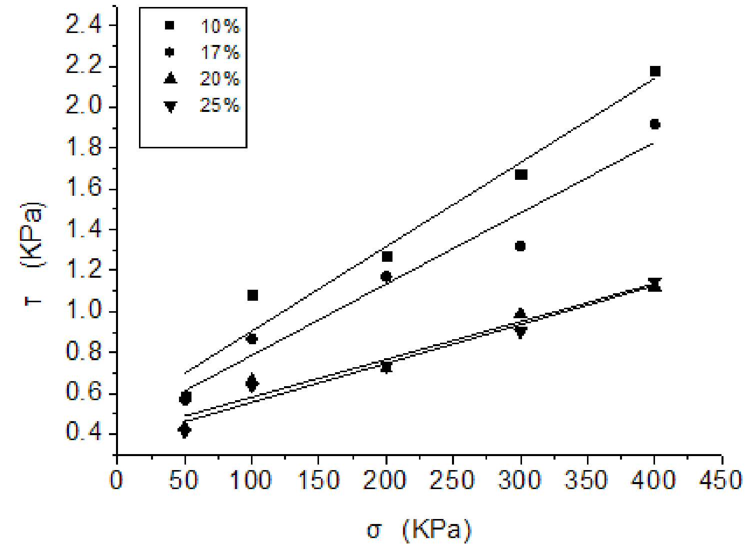

Figure 3. Relation curves between σ and τ

The typical curve is shown in Figure 3. The shear strength increases with the increase of normal stresses which is in accordance with engineering practice in Coulomb's law. Fitting equation see Formula 1.

$$y=A+x\tan B \tag{1}$$

When water content is 10%, A_1=0.4936 and B_1=0.23;
When water content is 17%, A_2=0.4386 and B_2=0.20;
When water content is 20%, A_3=0.3966 and B_3=0.11;
When water content is 25%, A_4=0.3662 and B_4=0.11;

The inclination angle of the fitting line is the internal friction angle φ(˚). The intercept of straight line in ordinate is cohesive force C(kPa).

When water cement ratio is 0.4 and the water content of clay is 10%, φ= 0.23 and C= 0.49kPa;
When water content of clay is 17%, φ= 0.20 and C= 0.44kPa;
When water content of clay is 20%, φ= 0.11 and C= 0.40kPa;
When water content of clay is 25%, φ= 0.11 and C= 0.37kPa.

When the water content increases, the shear strength decreases and the internal friction angle decreases rapidly. The soil is close to saturation when the water content is more than 20%, that the lines of shear strength are basicly overlapped.

(3) When the water-cement ratios of cement paste are different, the relationship between internal friction angle and water content is shown in Figure 4.

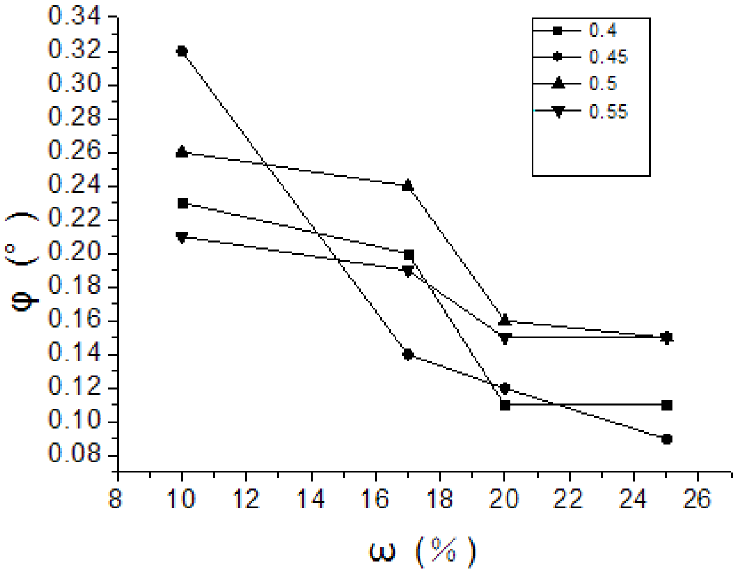

Figure 4. Relation curves between ω and φ

As shown in Fig. 4, when the water cement ratio is constant, the internal friction angle decreases with the increase of water content, which shows that the electric double layer on the surface of micro-clay particles changes the properties of water on the surface of particles and becomes bound water when the water content increases[8]. This water film becomes thicker, which plays a role of lubrication and make the angle of internal friction smaller. When the water content increases to a certain extent, the lubrication effect of water film is not obvious, which represented that the internal friction angle decreases slightly when the water content is 20%~25%.

(4) When the water-cement ratios of cement paste are different, the relationship between moisture content and cohesion is shown in Figure 5.

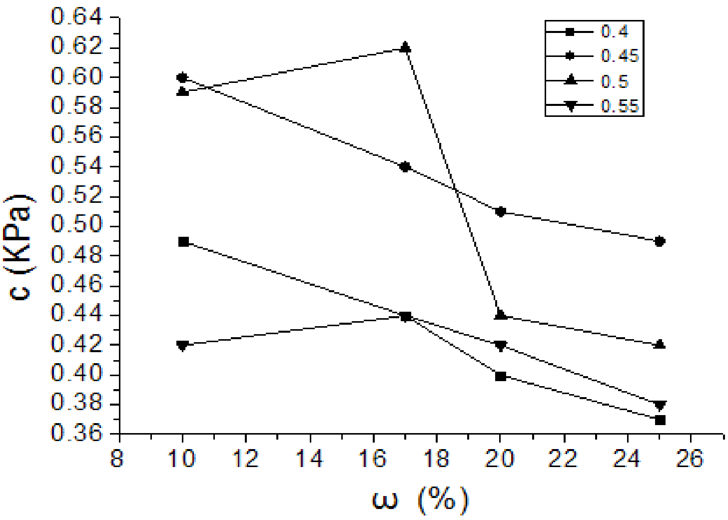

Figure 5. Relation curves between ω and c

As shown in Figure 5, with the increase of water content, the cohesion increases first and then decreases. Peak point of cohesion occurs when water content is 17%. It can be seen that the cohesive force is more discrete. Analysis of Gao Dazhao shows that the cohesive force mostly accords with lognormal distribution[9]. Fan Mingqiao believes that the proportion of cohesion force in normal distribution is 42.3%, and the other is lognormal distribution[10].

(5) When water content of clay is different, the relationship between internal friction angle and water cement ratio is shown in Figure 6.

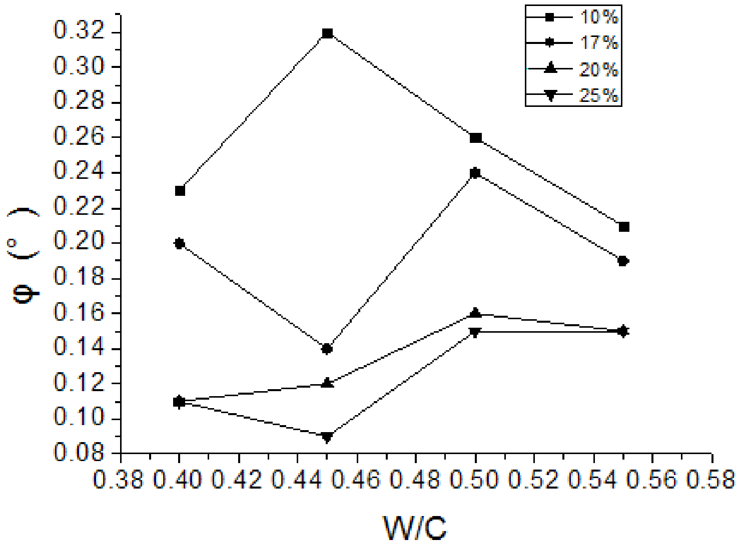

Figure 6. Relation curves between W/C and φ

As shown in Fig. 6, the internal friction angle increases first and then decreases with the water cement ratio when the moisture content is 10%. When the water cement ratio is 0.47, the peak value is reached, which is the best for engineering security. When the moisture content is 17%~25%, the internal friction angle increases with the increase of water cement ratio.

(6) The relationship curve between cohesion and water cement ratio is drawn as Figure 7.

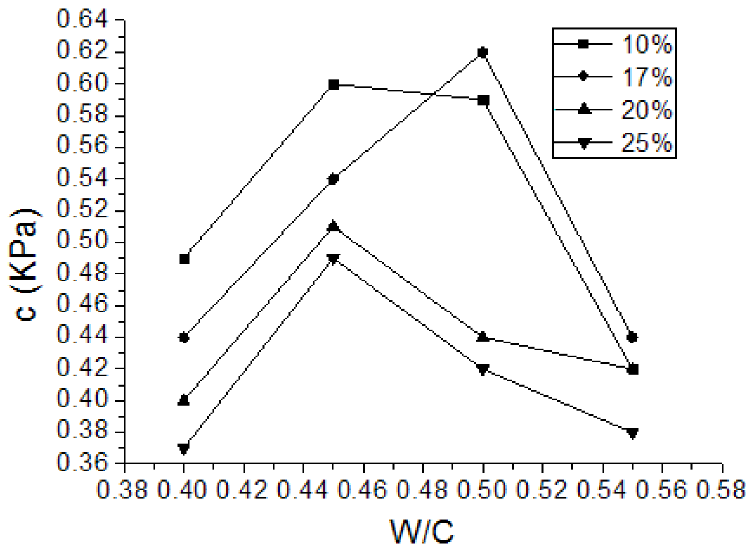

Figure 7. Relation curves between W/C and c

As shown in Figure 7, the cohesion increases first and then decreases with the water cement ratio when the water content is constant. When the water cement ratio is 0.45, the cohesion reaches the peak value.

5. Conclusion

(1) Among the indexes of shear strength in the contact surface, the internal friction angle decreases with the increase of water content. The change of internal friction angle tends to be stable when moisture content is 20%~25%, that soil is closed to saturated. Cohesion increases first and then decreases with water content. And the peak of cohesion appears when moisture content is 17%. In this process, bound water in the soil plays a significant role.

(2) The roughness of contact surface changes obviously because of the changing in water cement ratio of cement paste, which presented that the cohesion increases first and then decreases with the water cement ratio. And the cohesion reaches its peak value when the water cement ratio is 0.45. The internal friction angle increases first and then decreases with the water cement ratio. And the internal friction angle reaches the peak value when the water cement ratio is 0.5, which shows the grouting materials commonly used in engineering chosen the water cement ratio as 0.4~0.5 was reasonable and feasible such as grouting bolt, grouting soil nail, etc.

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