

## Experimental Research on Failure Behavior of Soil around Pile under Compression

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### Abstract

*Through small scale model laboratory experiments, the article proves that the effect of pile and soil work together of Push-extend Multi-under-reamed Pile under compression, and identifies failure modes and failure principle of soil around the pile, and for further determining ultimate bearing capacity of soil under compressive state about the Push-extend Multi-under-reamed Pile, it provides a reliable foundation. At the same time, this article provides a new method for laboratory test, which calls small scale model laboratory experiments used for research about soil body failure states of pile foundation.*

**Keywords:** push-extend multi-under-reamed pile, compression, failure behavior, ultimate bearing capacity

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### 1. Introduction

Through theoretical calculation and analysis, it has been formed qualitative analysis about the mechanism of pile and soil working together for the Push-extend Multi-under-reamed Pile. To further research mechanism of soil failure, through small model test this paper will research the failure forms of soil body under Push-extend Multi-under-reamed of pile while the loads act at the Push-extend Multi-under-reamed Pile, and observe the situation of pile and soil working together to check and prove theoretical analysis conclusions. The article forms a foundation for further studying the ultimate bearing capacity of the Push-extend Multi-under-reamed Pile.

Due to the aim of this test is to study form of soil failure, therefore the test uses small proportion of the test model of the element, the specimens are designed with different diameter, shape, number of the Push-extend Multi-under-reamed of bearing, and the clay, which usually is used as subsoil, is applied as a soil for testing, through simulating actual behavior of pile and soil, the models and device for testing will be built with the test completed in the laboratory. A new method is applied in this test, that is the specially produced half of pile specimen, that overcomes some disadvantages of traditional method, such as only test data can be known, but the changes of the soil can not be observed, while the new method provided in the article will observe clearly the whole changing process of soil body from beginning to load until failure, and in the experiment the data of strain and displacement can be collected, the failure behavior of soil body can be observed and drawn, and the behavior of soil body at ultimate failure will be shoot, so the test results can be analyzed according to above data collected.

### 2. Models and Devices for Testing

#### 2.1. The Specimens and Materials for Testing

The clay from actual engineering field is used as the testing soil, the measured parameters of soil: the natural moisture is 7.2%, the limited magnitude of liquid state  $\omega_L=22.1\%$ , the limited magnitude of plastic state  $\omega_p=8.9\%$ , the compressive modulus  $E_s=2.8 \times 10^{-2} \text{N/mm}^2$ , the density  $2.11 \text{N/mm}^3$ .

Due to the small scale specimen, and the specimen material will produce few effects for test results, so the specimen model will be made by iron material, the diameter of main pile is 10 mm, height of bearing push-extend reamed is 20mm. They are divided two broad groups that 16 specimens which have different diameter, shape, numbers and the location of bearing push-

extend reamed, among them, each group include 8 specimens, respectively for pile with single push-extend reamed and pile with push-extend multi-under-reamed, the sizes and specifications of specimens as shown in Table 1.

Table1. The Sizes and Specifications of the Specimens

The No. of single bearing push-extend reamed	Diameter of bearing push-extend reamed	Shape of bearing push-extend reamed	The No. of double bearing push-extend reamed	Diameter of bearing push-extend reamed	Shape of bearing push-extend reamed
Single, No.1	20 mm	Single slope	Double, No.1	20 mm	Single slope
Single, No.2	20 mm	Double slopes	Double, No.2	20 mm	Double slopes
Single, No.3	30 mm	Single slope	Double, No.3	30 mm	Single slope
Single, No.4	30 mm	Double slopes	Double, No.4	30 mm	Double slopes
Single, No.5	40 mm	Single slope	Double, No.5	40 mm	Single slope
Single, No.6	40 mm	Double slopes	Double, No.6	40 mm	Double slopes
Single, No.7	50 mm	Single slope	Double, No.7	50 mm	Single slope
Single, No.8	50 mm	Double slopes	Double, No.8	50 mm	Double slopes

## 2.2. Test Device and Equipments

Because the proportion of the specimen is small and the way of loading is manual, so manually loading device is produced as shown in Figure 3. In addition to loading devices, the following equipment are used in the test: (1) the glass container, which is made of 10mm thick glass, and the size is 600mm×300mm×200mm (used for installing soil and embedding specimens); (2) Sensors (used for testing loading value); (3) Standard sensors and Jack with 2 ton limit (for measuring the magnitude of external loads per unit strain); (4) YD-88 portable super strain gauge (for collecting strain data); (5) Displacement meter (for testing the displacement of top point of pile); (6) SP-4A displacement digital instrument (for collecting displacement data); (7) Digital camera (used to take phone of the behavior of pile and soil and the failure state of soil before and after test); (8) Media computer (used for processing of test data later).

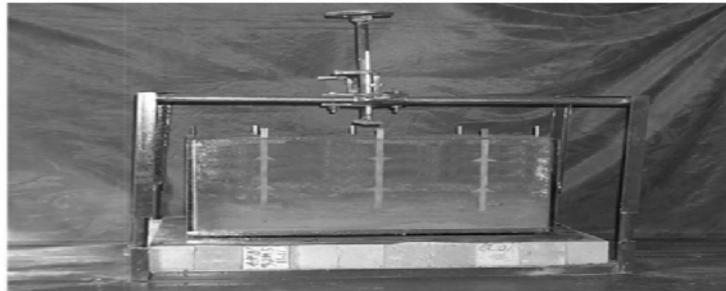


Figure 3. The Photograph of Device for Testing

## 3. Test method and data processing

### 3.1. Test method

(1) In order to conservative observation of test results, the specimen is cut from middle plane, the surface cut will be fixed cling the surface of the glass container along vertical direction, and the top of the pile is higher than the glass container about 40mm in order to load.

(2) Glass container is filled with soil which is hierarchical compacted and placed into the loading device (see Figure 4).

(3) The loading device is fixed, they are connected that sensors, strain, gauges, displacement meter and displacement digital instrument (Figure 5 and 4). Gradually to load, at the same time, collect data of strain and displacement, and draw failure the form of the soil under bearing push-extend reamed at proper time.

**3.2. Test Results Coordinating**

According to test methods and procedures above, the tests are operated respectively with 16 specimens due to two groups, the data of test results collected is coordinated, and the contrast graphs of the data are produced, as shown in Figure 4 to Figure 7.

The contrast graphs of loads-displacements curve for pile with single bearing push-extend reamed.

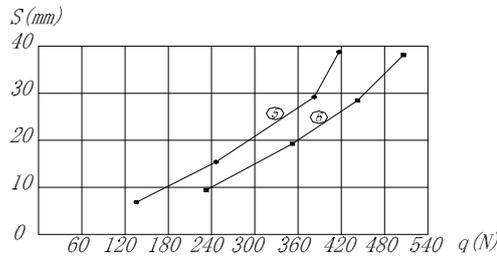


Figure 4. The Pile No. 1 and Pile No. 2

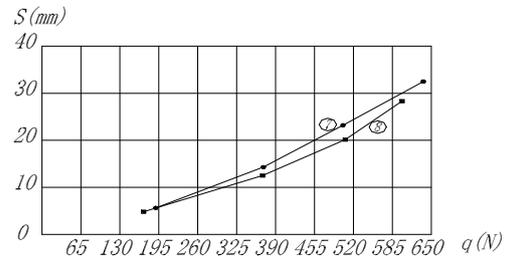


Figure 5. The Pile No. 3 and Pile No. 4

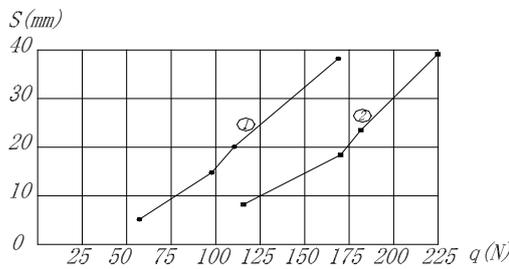


Figure 6. The Pile No. 5 and Pile No. 6

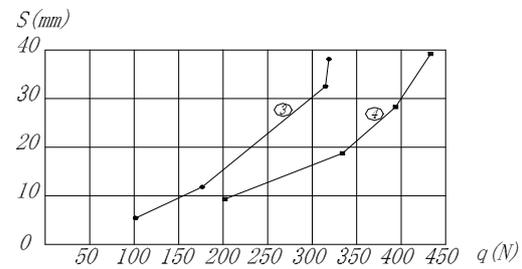


Figure 7. The Pile No.7 and Pile No. 8

The contrast graphs of before and after failure of soil under bearing push-extend reamed, for example, the single No. 3 is shown as Figure 8 and Figure 9 (Figure 8 is before testing, Figure 9 is after testing).

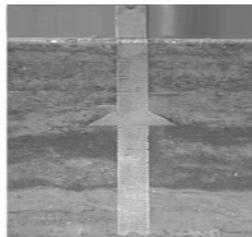


Figure 8. Before Testing

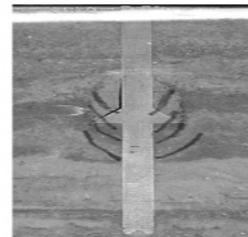


Figure 9. After Testing

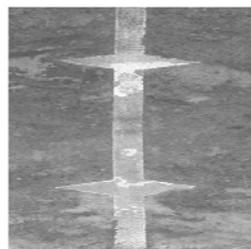


Figure 10 Before Testing

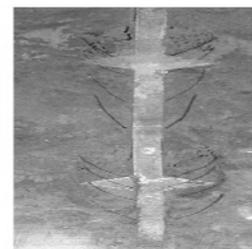


Figure 11. After Testing

The contrast graphs of before and after failure of soil under double bearing push-extend reamed, for example, the double No. 8 is shown as Figure 10 and Figure 11 (Figure 10 is before testing, Figure 11 is after testing).

#### 4. Conclusion

According to the load-displacement curve formed from the test data and the contrast photo before and after failure of soil body, we could clearly observe the failure form of soil, analyze the above test results, the following conclusions can be drawn:

Among all test piles, at the beginning of loading, soil body is compacted (vertical stress increases), it is in favor of improving bearing capacity of soil. The failure state of soil body above bearing push-extend reamed is basically the same, namely the top surface of it breaks away from soil body just when the displacement of pile occurs, and within a certain range above bearing push-extend reamed, the separation happens between soil around pile and pile (or produce horizontal tensile stress), therefore frictional force of the soil body within this range should not be considered in calculating bearing capacity. At the same time, failure behavior of soil body under bearing push-extend reamed is also basically similar, that is, soil body at the bottom of bearing push-extend reamed is damaged by shear force, the soil under bearing push-extend reamed from edge of it to pile slides within the sliding line about 30 angles. Thus indicates that the frictional force of soil around pile within this range should not be taken into account in calculating ultimate bearing capacity, and this range is larger.

Compare the test piles which have same diameter, height and different forms of bearing push-extend reamed, double slope of push-extend reamed pile has greatly large scope influence for soil than single slope, but double slope produces less displacement under the same load than single slope, it shows that the former have slightly higher bearing capacity. For the multi-under-reamed pile when the distance of the two adjacent bearing push-extend reamed is reasonable (such as clay, silt:  $\geq 2.5D$ ; sands:  $\geq 3.0D$ ), the impacts between them is very small, basically follows the soil failure regularity of the pile with single bearing push-extend reamed, just soil range damaged of the lower is smaller than the upper one. This shows that the first to bear the load is the upper one. When the distance of the two adjacent bearing push-extend reamed is smaller, it has great impacts between the upper and lower one, due to the distance of them is close to the sliding line scope of soil, soil failure is basically developed by shear failure of soil body, the soil body between bearing push-extend reamed cannot be fully effective. With the diameter increases, the sliding range of soil above and under also increases, it shows that the disk diameter bigger is not better, but there should be a suitable ratio between diameter of bearing push-extend reamed and diameter of pile.

In summary, this test has further proves failure behavior of soil around pile about the Push-extend Multi-under-reamed Pile and the agreement with conclusions of theoretical analysis, that is the setting of bearing push-extend reamed makes the separation of the soil body and pile within a certain range, the soil body under bearing push-extend reamed causes sliding failure, it fully prove that the current calculation formula of bearing capacity of single pile (simply superposition between pile side friction and pile tip resistance) have a certain irrationality, the article provides a reliable basis for further using the theory of sliding line to establish a new calculation model of bearing capacity of single pile and determining ultimate bearing capacity of soil body. And it provides a basis data for studying related factors affecting the bearing capacity of single pile. At the same time, the test method called half section of small model is used in this test, and it offers a new simple laboratory method for researching pile foundation.

#### Acknowledgment

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