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Finite Element Analysis of Factors Affecting the Determination of Bearing Capacity of Soft Soil Foundation by Screw Plate Load Test

Fangquan Li, Li Liu
Shandong University of Science and Technology, Qingdao 226590, China.

Abstract

In this paper, using the ABAQUS finite element numerical simulation software, the influence of the influence factors of the screw plate load test in the application of the soft soil foundation on the test results is analyzed. The results show that in the soft soil foundation, under the same conditions, the greater the test depth, the greater the value of the measured foundation bearing capacity, and this rule will be more obvious with the increase of the size of the load plate; In the screw plate load test, there is a plate diameter value. When the plate diameter is less than or greater than this value, the screw plate load test measures The characteristic value of the bearing capacity of the foundation and the size of the screw plate are negatively correlated, but the characteristic value of the bearing capacity measured by the screw plate smaller than the plate diameter is smaller than the characteristic value of the bearing capacity measured by the screw plate larger than the plate diameter.

Keywords

Screw Plate Load Test; Characteristic Value of Foundation Bearing Capacity; Finite Element Analysis.

1. Introduction

Soft soil foundation has high compressibility, low water permeability, low shear strength and obvious rheological properties. It does not meet the requirements for foundation bearing capacity, deformation and stability in road engineering, so it needs to be improved by foundation treatment Foundation strength, pre-construction and post-construction in-situ detection technology is essential for the evaluation of foundation treatment effect. In the in-situ testing technology, the flat-plate load test has a large workload and high cost, and is not suitable for working in groundwater-containing formations; static cone penetration cannot directly obtain the characteristic value of the foundation bearing capacity and cannot obtain the shear strength parameters of the soil. These traditional in-situ tests The limitations of experiments are becoming more prominent in engineering. Screw plate load test has many advantages such as large test depth range, simple test, low cost, etc. It can directly obtain foundation bearing capacity, and can also obtain mechanical parameters such as shear strength and deformation modulus. It can be compared with traditional in-situ in engineering. Tests are used in conjunction to achieve maximum engineering benefits. Studying the applicability of the screw plate load test in soft soil foundation can make the screw plate load test better applied to the detection of soft soil foundation, which has certain engineering significance and engineering application value.

Selvadurai[1] put forward the minimum size ratio to the undisturbed soil through laboratory experiments: c/a=0.125; b/a=0.25; t/a=0.02 (2a: screw plate head diameter; 2b: pitch; 2c: transmission Force rod diameter; t: thickness of screw plate); Selvadurai and Nicholas[2] believe that the data measured by large diameter screw plate (350mm) in soft clay is more accurate; For this point of view, many scholars have also done relevant experiments to confirm; Selvadurai et al. [3] showed that when the embedding depth of the screw plate is greater than 6-8 times the diameter of the screw plate, the

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influence of the free boundary on the plate deflection is almost negligible. Therefore, the test depth is greater than this depth, and the screw plate load test can be regarded as a test in an infinite elastic body. Qinghe Huang [4] believed that the screw plate load test is not only suitable for deep foundation soil with a buried depth of more than 3m, but also for shallow foundation soil with a buried depth of more than 1 meter and less than 3 meters. Jingpei Li [5] found in the test that the loading rate during the test will affect the results of the load test, but it will decrease with the increase of the buried depth; Zhaoyu Xie [6] pointed out that the suitable depth of the ordinary screw plate is generally within 12m, and the depth is too large. The force-transmitting rod will produce greater deflection, and the test equipment needs to be improved to solve the problems of deflection, uneven soil stress, and local damage caused by excessive depth. The screw plate load test evolved from the plate load test. Both the test method and the result analysis are based on the plate load test. Therefore, the plate load test is set as the control test. In order to eliminate the unknown interference of the field test soil, the choice is limited. The meta-analysis software ABAQUS performs numerical analysis.

2. Finite element design

2.1 Finite element design

2.1.1 Model size

The size of a single soil model is set to 1m*1m*1m, and the center of the soil surface is the penetration point of the load test. According to the boundary effect, the influence range of the load test on the soil is about 3 times the diameter of the center of the load plate. Circular range, therefore, the foundation boundary conditions of the model will not affect the calculation results of the model.

2.1.2 Basic assumption

The model uses three-dimensional homogeneous materials to study, and the following assumptions are made when modeling

(1)The elastic model is selected for the screw plate loading device, and the Mohr Coulomb model and the linear elastic model are used in combination for the entire soil constitutive model.

(2)Boundary conditions are set around the foundation and the bottom surface. The four sides are not displaced perpendicular to the horizontal direction of the surface, and the bottom surface is not displaced in both horizontal and vertical directions.

(3)The model foundation soil is made of uniform soft clay material, and the part of the load test device is made of rigid metal material.

2.1.3 Model parameters

According to the geotechnical test, the weight of the soil taken in this test is 18kN/m3, and the detailed parameters of the soil and screw plate loading device are shown in Table 1.

Table 1. Detailed material parameters of numerical model

Material name	Elastic modulus E/(kPa)	Poisson's ratio /μ	Density ρ/(kg/m^3)	Cohesion c/kPa	Internal friction angle φ/°
Soft clay	10000	0.25	1800	15	0
experimental device(steel)	206000	0.3	8000	-	-

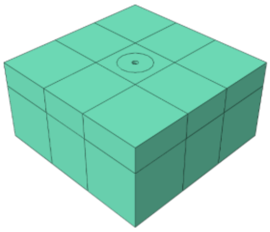

Fig. 1 Soil 1 (soft clay)

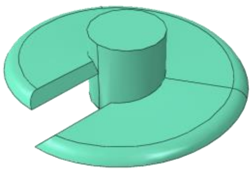

Fig. 2 Screw plate (steel)

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2.2 Establishment of material properties

In the attribute module, assign materials to the created components, mainly define the materials of the soil and load test device. The model material definition partitions are shown in Fig. 1-2 (all with 160mm board diameter as an example).

2.3 Setting of analysis step

The setting of the analysis step in ABQUS is very important in the entire numerical simulation, especially the setting of the analysis step of the ground stress balance. The ground stress balance analysis steps of the two models in this numerical model do not use the traditional Geostatic analysis step, but use the General General analysis step, set the maximum time increment step to 100, the initial step size of 0.1, the maximum step size of 1, and the minimum step size of 1e-5.

The two models of this numerical model set a total of three analysis steps, the initial initial analysis step, the Geo analysis step and the Load analysis step. In the Load analysis step, set the maximum time increment step to 100, the initial step size to 0.01, the maximum step size to 1, and the minimum The step size is 1e-5. Due to the Mohr-Coulomb model, asymmetric algorithms are selected for all analysis steps.

2.4 Simulation of the construction process

Due to the need to excavate the foundation soil during the screw plate load test, the soil at the bottom of the hole will swell after excavation. The life and death element method is used to remove part of the excavated soil and activate the flat load plate element, which cannot be guaranteed. The coupling relationship between nodes and surface elements needs to be processed, which increases the difficulty of model calculation. In order to simplify the model, part of the excavated soil was removed in the initial analysis step, plane load plate elements were introduced, and materials were assigned to each component, and interactions were set to define the contact relationship between surfaces and the flat load plate. Set the rigid body constraint, and apply vertical load to the entire soil surface in the Geo analysis step of the Load module, simulate the confining pressure state at a depth below 5m-7m for load test, and set the load plate drop depth 10mm as the termination loading condition.

2.5 Meshing

In the finite element grid module, the model is divided into grids. First, the parts are planted. the grid size of the central area is set to 0.015, and the element shape is 4 Faceted body, the division technology is Free drawing method, the element type is 3D Stress, the outer edge mesh is from large to small, the maximum size is 0.05, the minimum size is 0.015, the element shape is hexahedron, and the element type is 3D Stress. For the load plate part, the grid The size is set to 0.005, the element shape is a tetrahedron, the division technique is Free drawing, the element type is 3D Stress, and the screw plate load test numerical model grid is shown in Fig. 3.

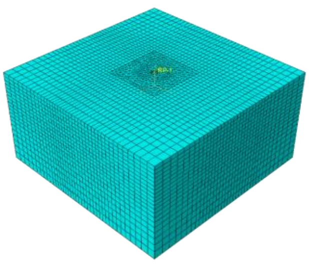

Fig. 3 Grid of screw plate load test model

3. Numerical simulation calculation process and result analysis

3.1 Numerical simulation calculation process

The soil model specification is 1m*1m*1m. In order to simulate the soil confining pressure environment at depths of 5m, 6m and 7m below the ground surface, the same pressure of 5m, 6m, 7m

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thickness of the soil is applied to the entire soil surface in the Geo analysis step. And limit the horizontal and vertical displacement of the four sides. In the Load analysis step, using the displacement control method, set the load plate to drop 10mm as the termination condition for pressurization. In the numerical model, the contact surface between the load plate and the soil is assumed to be smooth and frictionless. The center point of the upper surface of the load plate is set as the reference point, and rigid body constraints are set for the overall components of the load plate. Draw the grid, calculate and derive the relationship curve between the characteristic value of the bearing capacity and the sinking displacement of the load plate.

3.2 Analysis of calculation results

The screw plate load test is compared with the screw plate load test. There are three commonly used screw plate sizes, the plate diameters are 113mm, 160mm, and 252mm respectively. Therefore, The test situation of the characteristic value of the bearing capacity of the soil foundation at a depth of 5m, 6m, 7m, a total of 9 examples, three sizes of screw plate load test and different depth test displacement results are shown in Fig.4-12.

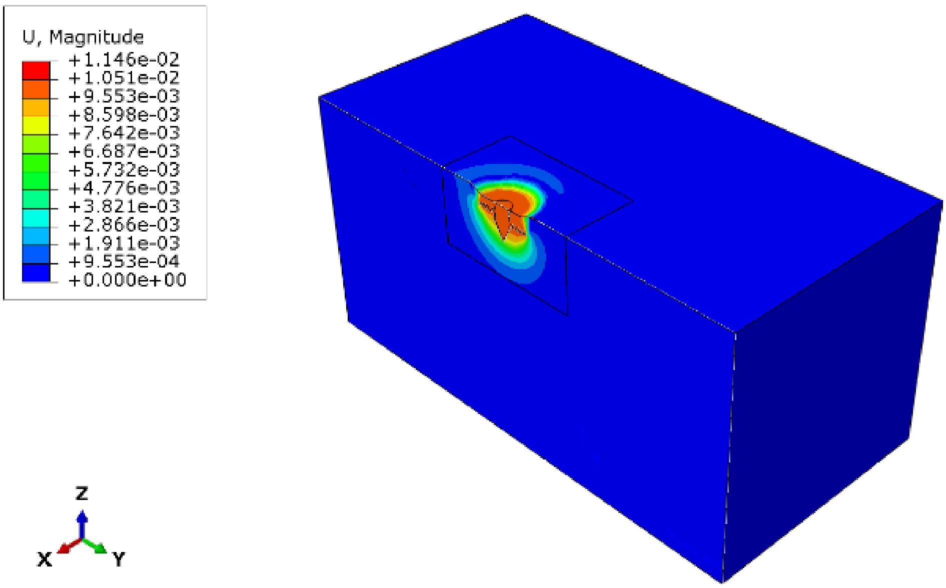

Fig. 4 Displacement nephogram of SPLT (113mm) 5m depth

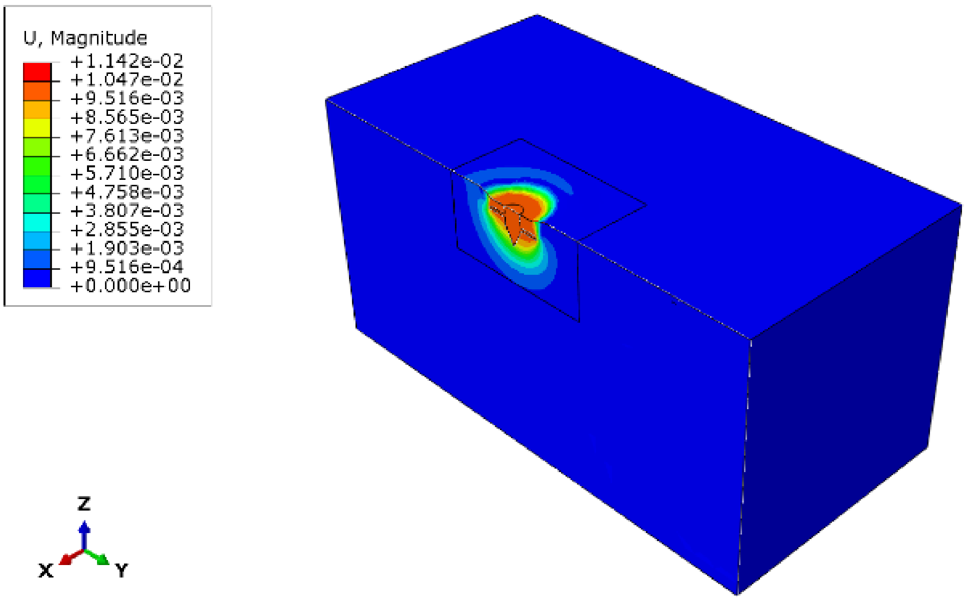

Fig. 5 Displacement nephogram of SPLT (113mm) 6m depth

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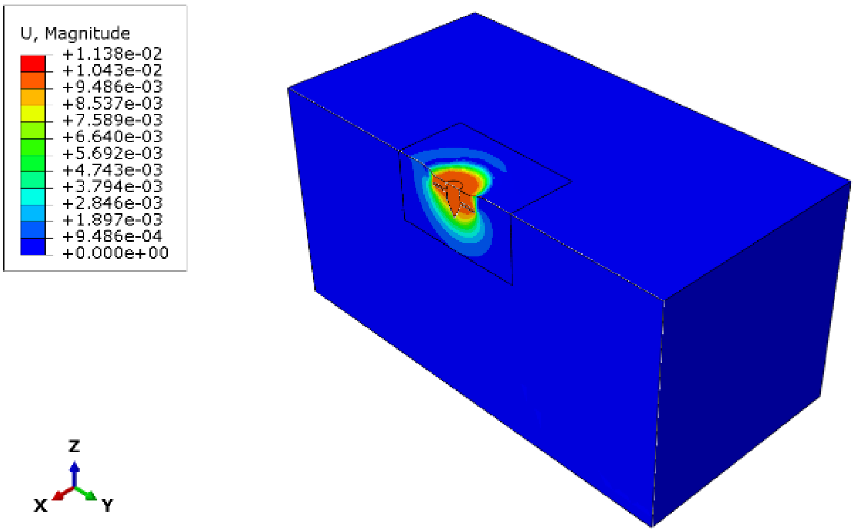

Fig. 6 Displacement nephogram of SPLT (113mm) 7m depth

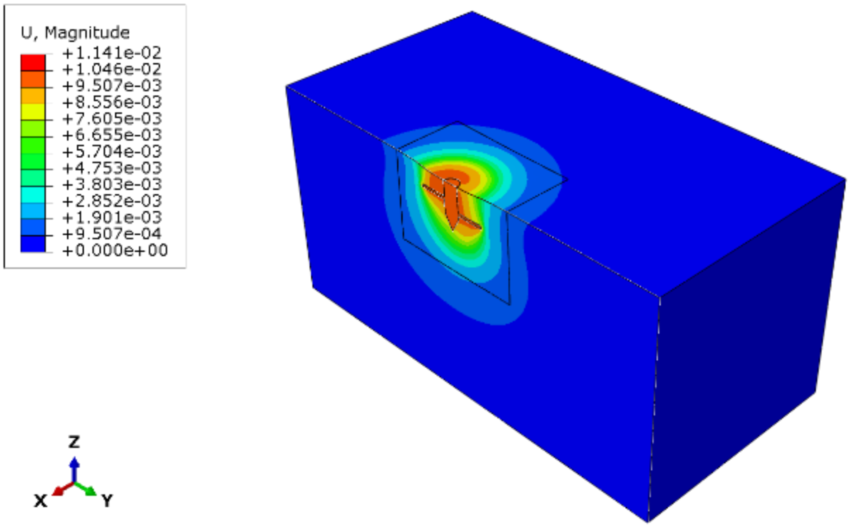

Fig. 7 Displacement nephogram of SPLT (160mm) 5m depth

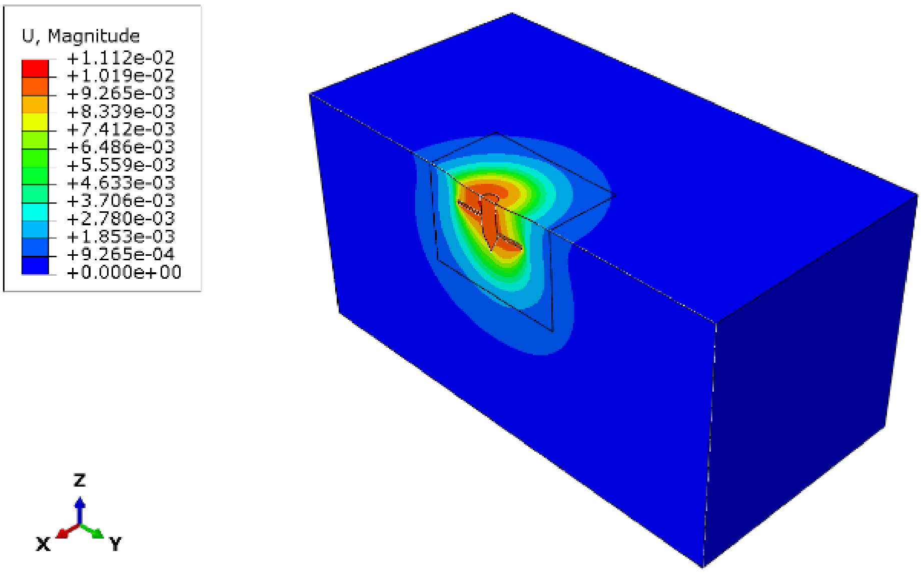

Fig. 8 Displacement nephogram of SPLT (160mm) 6m depth

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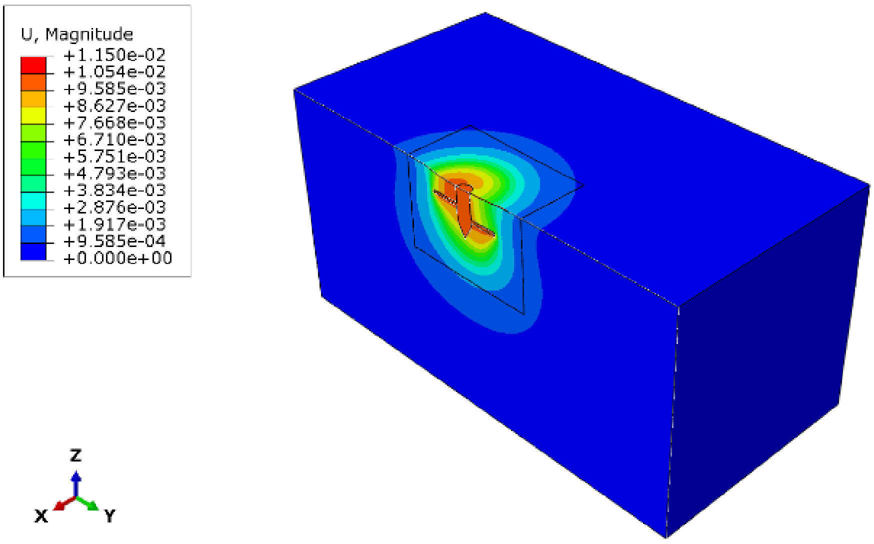

Fig. 9 Displacement nephogram of SPLT (160mm) 7m depth

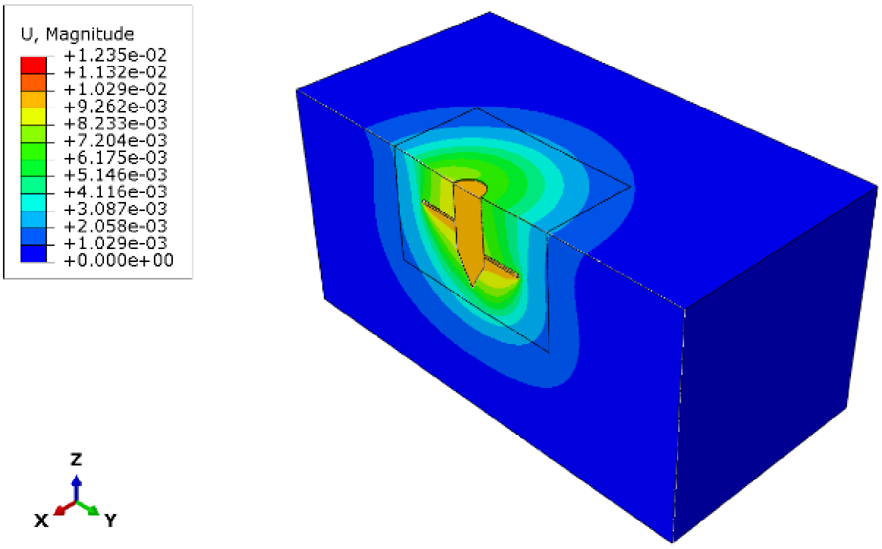

Fig. 10 Displacement nephogram of SPLT (252mm) 5m depth

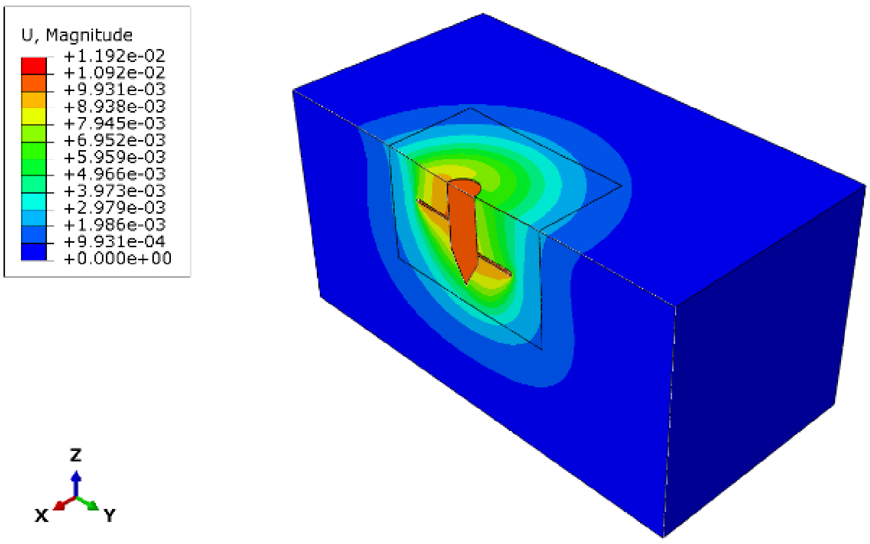

Fig. 11 Displacement nephogram of SPLT (252mm) 6m depth

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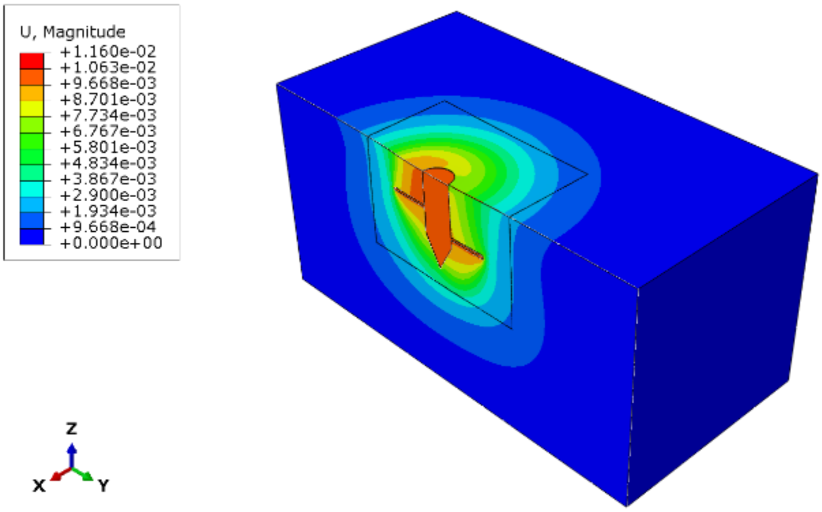

Fig. 12 Displacement nephogram of SPLT (252mm) 7m depth

Extract the force and settlement value of the load plate under the vertical load, and draw the P-S curve of the screw plate load test, as shown in Fig.13-15.

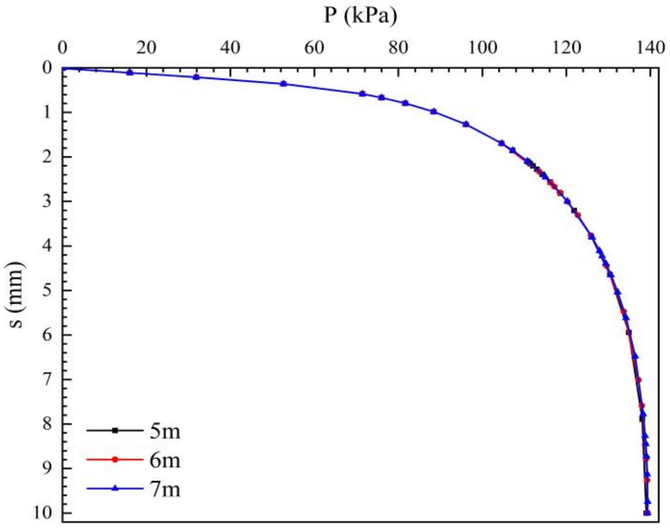

Fig. 13 P-S curves of 113mm SPLT at different depths

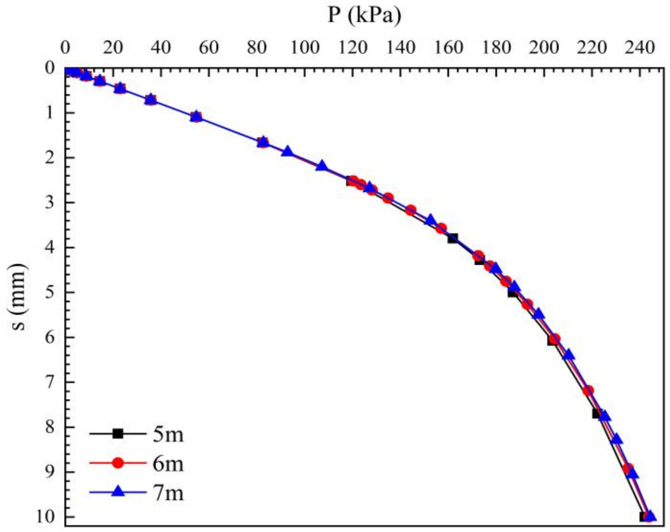

Fig. 14 P-S curves of 160mm SPLT at different depths

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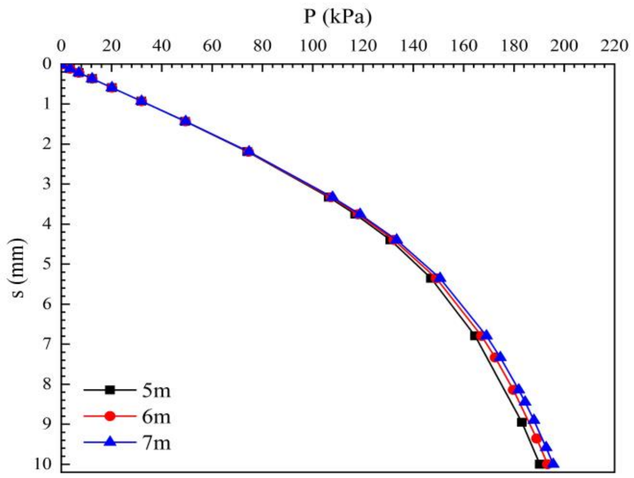

Fig. 15 P-S curves of 252mm SPLT at different depths

The pressure value corresponding to the settlement value of 0.015 times the radius is the characteristic value of the foundation bearing capacity of the soil, see Table 2.

Table 2. Characteristic values of foundation bearing capacity measured at different depths by screw plate load test

Board diameter /mm	Test depth /m	Characteristic value of foundation bearing capacity /kPa
113	5	104.6
113	6	104.6
113	7	104.7
160	5	117.4
160	6	118.2
160	7	119.8
252	5	115.0
252	6	115.4
252	7	115.6

Draw the characteristics of the foundation bearing capacity measured at different depths for three screw plate load tests with different plate diameters as shown in Fig.16.

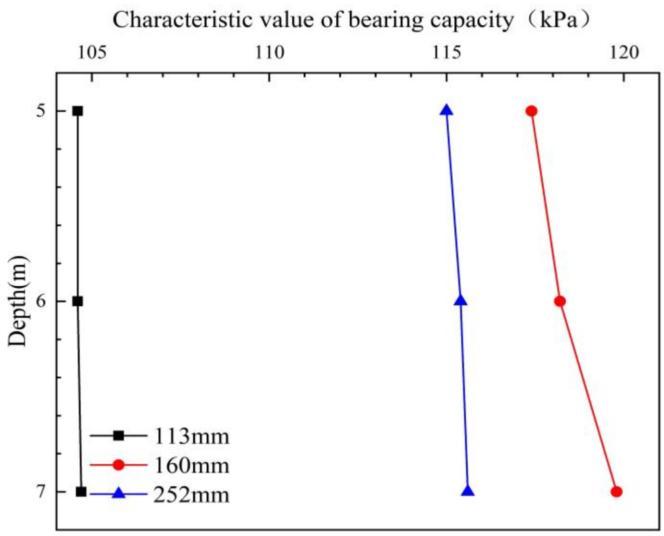

Fig. 16. Comparison of characteristic values of foundation bearing capacity measured at different depths by screw plate load test with different plate diameters

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It can be seen from the graph that in the uniform soft soil foundation, in the screw plate with three sizes of heads, there is a positive mutation between the plate diameter 113mm to 160mm and 252mm. This is the same as the characteristic value of the bearing capacity and the plate diameter measured in the plate load test. The negative correlation law is inconsistent, which is consistent with the conclusion that the characteristic value of the bearing capacity of the soft soil foundation measured by the 160mm plate diameter screw plate load test in the indoor model test part is greater than the foundation bearing capacity value measured by the smaller size 113mm plate diameter screw plate; 160mm plate The characteristic value of the measured bearing capacity is similar to the 252mm plate diameter, and conforms to the rule that the characteristic value of the measured bearing capacity at the same depth in the plate load test is negatively correlated with the plate diameter; the characteristic value of the measured foundation bearing capacity is positively correlated with the depth. , The larger the diameter of the board, the more obvious this change law is manifested.

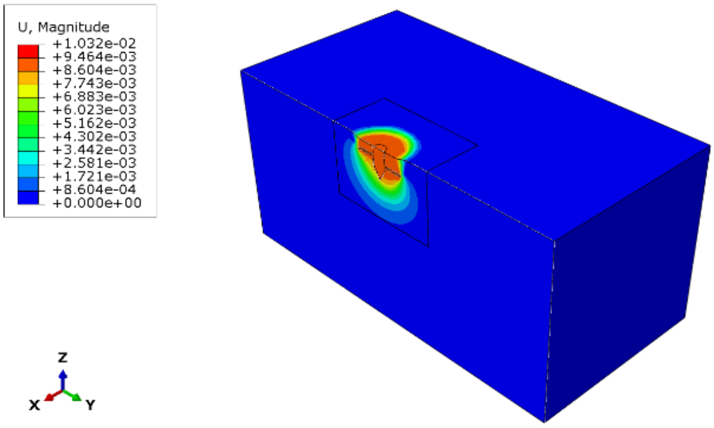

Fig. 17 Displacement nephogram of SPLT (138mm) 5m depth

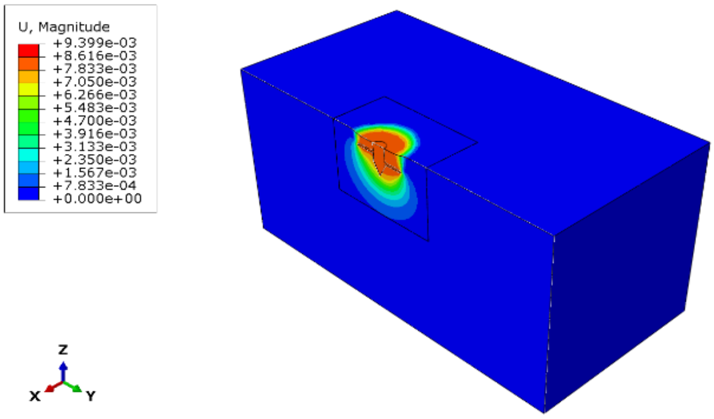

Fig. 18 Displacement nephogram of SPLT (138mm) 6m depth

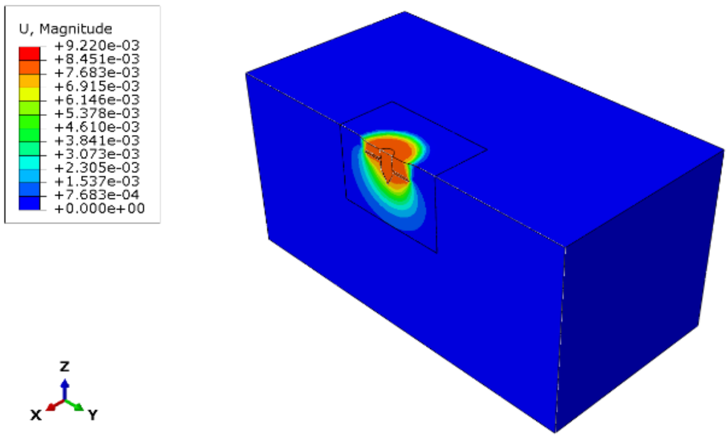

Fig. 19 Displacement nephogram of SPLT (138mm) 7m depth

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For soft soil, the screw plate load test has a size effect. It is guessed that there is a size value of the plate diameter of 113mm and 160mm, which is set as d. When the plate diameter is less than d or greater than d, the characteristics of the foundation bearing capacity measured by the screw plate load test The value has a negative correlation with the size of the screw plate, but the characteristic value of the ground bearing capacity measured by the screw plate smaller than d plate diameter is smaller than the characteristic value of the measured bearing capacity of the screw plate larger than d plate diameter. In order to further explore this law, add a group In the numerical model, the size of the screw plate is 138mm and the area is 200cm2. Other parameters are kept consistent with the previous calculation example. The displacement cloud is shown in Fig.17-19.

Extract the force and settlement value of the load plate under the vertical load, and draw the P-S curve of the plate load test, as shown in Fig.20.

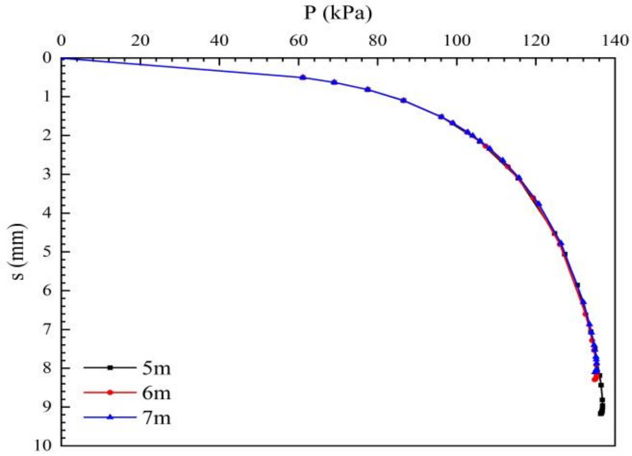

Fig. 20 P-S curves of 138mm SPLT at different depths

The pressure value corresponding to the settlement value of 0.015 times the radius is the characteristic value of the foundation bearing capacity of the soil, Table 3.

Table 3. Characteristic values of foundation bearing capacity measured at different depths in 138mm plate diameter screw plate load test

Board diameter /mm	Test depth /m	Characteristic value of foundation bearing capacity /kPa
138	5	100.8
138	6	100.9
138	7	101.0

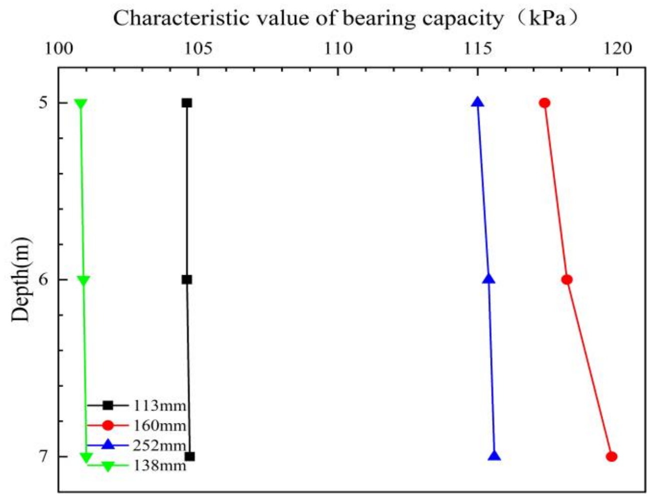

Fig. 21 Comparison of characteristic values of foundation bearing capacity measured at different depths by screw plate load test with different plate diameters

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For the analysis of the supplementary example results, it is in line with the conjecture. In the application of soft soil foundation, the screw plate load test has a size effect on the foundation bearing capacity test. There is a size value of the plate diameter of 113mm and 160mm. When the plate diameter is less than or When the value is greater than this value, the characteristic value of the foundation bearing capacity measured by the screw plate load test is negatively related to the size of the screw plate, but the characteristic value of the foundation bearing capacity measured by the screw plate smaller than the plate diameter is greater than that of the screw plate larger than the plate diameter. The characteristic value of the measured bearing capacity is small.

4. Conclusion

In soft soil foundation, under the same conditions, the measurement result of the soil foundation bearing capacity of the screw plate load test is greater than that of the same size plate load test, the characteristic value of the foundation bearing capacity The measured value and depth are positively correlated, that is, the greater the test depth, the greater the measured foundation bearing capacity value, and this rule will be more obvious with the increase of the size of the load plate. In the screw plate load test, there is a plate diameter value. When the plate diameter is less than or greater than this value, the characteristic value of the foundation bearing capacity measured by the screw plate load test is negatively correlated with the screw plate size, but it is smaller than the plate diameter. The characteristic value of the bearing capacity of the foundation measured by the screw plate with a larger diameter is smaller than the characteristic value of the bearing capacity measured by the screw plate with a larger diameter.

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