Study on the Characteristic Value of Bearing Capacity of Foundation Soil

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Abstract

Based on the analysis and comparison of various methods for detecting the characteristic value of Foundation Soil Bearing Capacity, the method for selecting the characteristic value in the early stage of survey and design or in the early stage of foundation construction is expounded. According to the test points, influencing factors and soil properties of different in-situ tests, the application range of different detection methods is discussed, the matching between different soil layers and detection methods is summarized, and a scientific and reasonable idea of choosing characteristic values is put forward, which provides a useful reference for investigation and design, engineering construction and other work.

Keywords

Pressure Plate Test; Standard Penetration Test; Dynamic Penetration Test; Static Penetration Test.

1. Introduction

The foundations are weak and the earth shakes. With the increasing height, span and weight of buildings, the safety and stability of foundation has been widely concerned and valued by the industry. In particular, the accuracy of the characteristic value of foundation soil bearing capacity is directly related to the stability of the whole building. Therefore, it is urgent to optimize the correct value and verification of the characteristic value of foundation soil bearing capacity.

The characteristic value of foundation soil bearing capacity is not only closely related to soil quality, but also depends on the design type of foundation, buried depth, groundwater level, load action and other factors. However, in the early stage of the investigation, the foundation size and upper load are not clear, so the bearing capacity characteristic value provided in the geological exploration report should be corrected and verified by in-situ testing before subsequent construction can be carried out. It becomes particularly important to adopt appropriate detection methods to determine the bearing capacity characteristic value.

2. Eigenvalue Detection Method

2.1 Pressure Plate Detection

The pressure plate load test is a widely used in-situ test method with reliable results. The test is to set up a load platform as a reaction device, and apply the load on a rigid bearing plate of a certain size by using a jack. The settlement of foundation soil under each level of load is detected, and the bearing capacity of the foundation can be measured more accurately. Since the test result did not consider the foundation type and buried depth, the final value should be corrected. The implementation contents of the test project are as follows:

(1) Application scope: natural foundation and artificial foundation.

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(2) Test points: the maximum test load of the platen test (soil layer) of the foundation acceptance test before construction is not less than 2 times of the characteristic value of the design bearing capacity, and the rock foundation is not less than 3 times; The area of pressure plate should be calculated in combination with the soil condition. The loading mode should adopt the slow maintenance load method; The point test elevation is consistent with the design elevation of the foundation bottom. When there is groundwater, it should be treated with precipitation first, and then installed with instruments and equipment. The test can only be started after the groundwater level is restored. The spacing of pressure plate, weight platform and base pile shall meet the requirements of the code; The load pressure should meet the relative stability standard of bearing plate settlement; Termination loading and eigenvalue judgment should meet the specification requirements.

(3) Influencing factors: area of pressure plate, elevation of detection point, operation of equipment, weather, etc.

(4) Result correction: according to the calculation formula of "Code for Design of Building Foundation" (GB 50007-2011).

$$f_a = f_{ak} + \eta_b(\mathrm{b}-3) + \eta_d \mathrm{r}_m(\mathrm{d}-0.5) \tag{1}$$

In the formula: fa- The modified characteristic value of foundation bearing capacity;fak- Characteristic value of foundation bearing capacity;ηb, ηd- Correction factor of foundation width and buried depth; rm- The weighted average weight of soil above the foundation bottom;b, d- Foundation width and buried depth.

2.2 Indoor Testing and Eigenvalue Calculation

Through laboratory tests on foundation soil core samples, soil property parameters such as weighted average weight, internal friction Angle and cohesion of soil layer above foundation bottom are tested. According to the plastic state or limit state formula, the characteristic value of the bearing capacity of the foundation soil is obtained by the calculation method of the theoretical formula.

(1) Calculated according to the plastic state, the formula to solve the eigenvalue is as follows.

$$f_a = \frac{\pi(r_m d + c_k cot\varphi_k)}{cot\varphi_k + \varphi_k - \frac{\pi}{2}} \tag{2}$$

In the formula: fa- Characteristic value of foundation bearing capacity;

ck, φk- Standard values of cohesion and internal friction Angle.

(2) Calculated according to the limit state, the formula to solve the eigenvalue is as follows.

$$f_u = c_k N_c \varepsilon_c + r_0 d N_d \varepsilon_d + \frac{1}{2} r b N_b \varepsilon_b \tag{3}$$

$$f_a = \frac{1}{2} f_u \tag{4}$$

In the formula: fu- Ultimate bearing capacity;

Nc, Nb, Nd- Bearing capacity factor;

εc, εd, εb- Foundation shape factor.

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2.3 Standard Penetration Method

In the penetration test, 63.5kg core hammer was used to drop freely along the probe rod according to the specified drop distance (76cm), and the number of hammer hits of the penetrator was recorded. The characteristic value of the bearing capacity of the foundation soil was calculated by table lookup or insertion method, which was used to determine the soil layer properties. Using standard penetration test to evaluate or determine the bearing capacity of foundation is a relatively complicated problem, which involves too many uncertain factors. Therefore, the test result is generally used for reference comparison, not directly as the only decision value. The contents of the test items are as follows:

(1) Application scope: silt, sandy soil and cohesive soil.

(2) Key points of the test: drill to about 15cm above the soil layer elevation of the test, then change the standard penetrator after clearing the hole, drive into the test soil layer at the penetration rate of 15-30 blows/minute, and record the number of blows; The number of hammer hits of 15cm for the first time was excluded, and the number of hammer hits of 30cm continued into the soil was taken as the test result. If the soil layer is dense, the following calculation formula can be used to convert.

$$N = \frac{30n}{\Delta S} \tag{5}$$

In the formula: n-Number of hits;

ΔS-Corresponds to the amount of penetration.

(3) Influencing factors: length and perpendicularity of probe rod, influence of soil weight pressure, influence of groundwater.

(4) Result correction: The rod length can be corrected by searching the relevant specification and by the formula $N' = \alpha N$; The revised values can be used to evaluate the compactness of sand and silt (see Table 1) and the state of clay soil.

Table 1. Classification of natural sand compactness

N	compactness
N>30	dense
15<N≤30	Medium density
10<N≤15	Slightly dense
N≤10	loose

2.4 Dynamic Probe

Dynamic probing test is a common method to test soil engineering characteristics in geological investigation. The detection is based on the soil density, the use of the specified quality of the drop hammer, the standard size, standard shape of the probe into the soil, and record the hammer number, used to determine the soil layer engineering physical properties. Dynamic probing tests can be divided into light, heavy and super heavy categories. The operation methods are similar, and the main differences are the hammer weight, drop distance and diameter of the probe rod. The contents of the test items are as follows:

(1) Scope of application: Light probing test is suitable for clay, silt, silt, fine sand and other foundations; Heavy-duty probing test is applicable to gravel soil, sandy soil, clay soil and other foundations. Super heavy probing test is applicable to soft rock, gravel soil and other foundations.

(2) Test points: free drop hammer should be used in dynamic penetration test; The height of the contact rod on the ground should be less than or equal to 1.5m, and prevent eccentricity, tilt and shaking; For each 1m penetration, the rod is turned one and a half times.

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(3) Influencing factors: hammer weight, falling distance, perpendicularity of the probe rod.

2.5 Static Penetration

In static probing test, the conical probe is pressed into the soil at a set rate at a constant speed at static pressure, and the penetration resistance (including cone tip resistance, side wall friction resistance or friction resistance ratio) is measured. The soil layer is divided according to the size of the resistance, and the engineering properties of the soil are determined by calculation. Static penetration test is widely used in geological exploration because of its simple operation, convenience and short test time. The contents of the test items are as follows:

(1) Scope of application: It is suitable for soft soil, clay, silt, sandy soil and soil layer containing a small amount of gravel.

(2) Test points: the length of the probe rod should exceed the depth of the test hole 2.0 meters; The reaction force should be greater than the estimated maximum penetration resistance; The probe should be uniformly pressed vertically during the calibration period; Termination of penetration shall meet the requirements of the code.

(3) Influencing factors: rod length, reaction force, probe, operation.

3. Engineering Example

The geological condition is shown in Table 2 below. The groundwater level is below the bearing layer. Three different soil layers are intended to be used as the bearing layer, and various detection methods are used to test the bearing layer bearing capacity characteristic values, and the applicable scope and engineering positioning of each detection method are summarized.

Table 2. Engineering geological characteristics

Stratigraphic name	Layer thickness(m)	Depth of top surface (m)	Soil property
Sand soil	1	----	Medium density
clay	2	-1	Hard molding
Strongly weathered rock	8	-3	argillaceous

3.1 When the Proposed Bearing Layer is Sandy Soil Layer

(1) According to the P-s curve data (5 levels after loading) in the following table, The proportional limit of the curve is 240kPa; When the pressure is increased to 480kPa, the soil around the pressure plate is obviously extruded out, and the first load is taken as the ultimate load, half of which is 210kPa. The characteristic value is the smaller of the two, that is, fa=210kPa.

Table 3. P-s curve table of pressure plate detection

P(kPa)	240	300	360	420	480
S(mm)	13.10	17.18	25.99	37.41	51.58

(2) According to the indoor soil test data determined

$$c_k = 15\text{kPa}, \varphi_k = 22\,°, \text{r}_m = 19\text{kN/m3}, \text{e}=0.984$$

Combined with the theoretical formula, we can obtain:fa=189 kPa.

(3) According to standard penetration test data

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Corrected number of test hits N=18.6, By looking up the table and interpolation method: fa=240 kPa.

(4) According to the dynamic penetration test data

Using heavy - duty conical dynamic probe, measured by table lookup and interpolation method: fa=235 kPa.

(5) According to static penetration test data

$$fa=40ps+70=207kPa$$

According to the above results, Table 4 is summarized as follows:

Table 4. Comparative results of sand layer detection

Detection method	Platen detection	Laboratory test	Standard penetration	Dynamic probing	Static probing
eigenvalue(kPa)	210	189	240	235	207

For sand, data analysis shows that the bearing capacity characteristics of the bearing layer can be truly reflected by the test results of the pressure plate, and there are few influencing factors (except weather, groundwater level, etc.). The indoor test results of sand have a large deviation, mainly because the sampling, sealing and transportation processes will cause disturbance to the sample, destroy the sample structure, and lead to irregular differences in the test results. The results of laboratory test combined with theoretical calculation can be used as reference values to compare and verify the test results of other detection methods. It is advisable to use casing detection for dynamic probing and standard penetration test, otherwise hole collapse and bottom slag cleaning are easy to occur, resulting in larger test results. In sandy soil, as long as the equipment is well controlled without deviation, the static penetration detection data is real, and the test results are similar to the pressure plate detection data, which can be used as deterministic results.

3.2 When the Proposed Bearing Layer is Clay Layer

According to the sand calculation method and process, the clay layer calculation results are summarized as shown in Table 5:

Table 5. Comparison table of clay layer detection data

Detection method	Platen detection	Laboratory test	Standard penetration	Dynamic probing	Static probing
eigenvalue(kPa)	170	190	187	176	178

For clay, data analysis shows that there is a small difference between the results of platen detection, dynamic detection and static detection, while the discretization type of laboratory test and standard penetration test is relatively large. Optional platen detection, dynamic detection and static detection are the preferred methods for eigenvalue detection. The laboratory test calculation method and standard penetration test are compared.

3.3 When the Proposed Bearing Layer is Strongly Weathered Rock.

According to the sand calculation process, the calculation results are summarized in Table 6:

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Table 6. Comparison table of test data of strongly weathered rock

Detection method	Platen detection	Laboratory test	Standard penetration	Dynamic probing	Static probing
eigenvalue(kPa)	320	306	342	327	353

For strongly weathered rock, the results of pressure plate detection are close to those of dynamic exploration, while the results of laboratory test and standard penetration test have a large discrete type, and the deviation of static exploration results is the largest. Optional platen and dynamic probe detection are the preferred methods for characteristic value detection. Compared with laboratory test calculation method and standard penetration test, static contact detection of strongly weathered rock is less accurate, so it is recommended to select with caution.

4. Summary

(1) Through the comparative analysis of different detection methods, the test results of the pressure plate are reliable and applicable to a wide range, and the results can be used as the engineering design and acceptance standards. The result does not consider the weight of the building, foundation type and buried depth, so the modified eigenvalue should be used in the design. If it is impossible to carry out pressure plate testing due to site reasons, the testing method suitable for the corresponding soil quality should be adopted.

(2) The results of various testing methods of foundation soil bearing capacity are different. The examples of this paper can be used for reference to evaluate and choose each value. For example, pressure plate testing should reasonably select pressure plate and reaction device for soft soil and fill soil, so as to avoid non-test displacement; Laboratory test samples have great influence on cutting, sealing, transportation and test methods, and the results can be used as reference. The results of standard penetration test in different soil layers are relatively discrete and should be selected after comparison. The dynamic probe should control the influencing factors well and can be used as the alternative scheme of pressure plate. The static penetration results are related to the uniformity of soil, the thickness of interlayer, and the accuracy of equipment. The test results of sandy soil and cohesive soil are accurate, and the weathered rock strata or solitar soil layers should be carefully selected.

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