Discussion on Parameter Value and Application of Foundation Bearing Capacity Calculation Formula in Code for Design of Building Foundation

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Abstract: Article 5.2 of the Code for Design of Building Foundation gives the calculation formula of foundation bearing capacity. Some parameters in the calculation formula have the same symbols in front and back references, while the meanings represented by the parameters are different, resulting in the possibility of misuse by designers in the actual application process. According to the principle of soil mechanics, this paper discusses the situation that some parameters in the calculation formula of foundation bearing capacity are easily confused, which has certain reference value for correctly understanding the application of the calculation formula of foundation bearing capacity in foundation design.

1. Excerpts from Calculation of Bearing Capacity in Section 5.2 of Code for Design of Building Foundation \cite{1}

Article 5.2.2 of the code for design of foundation for building foundation stipulates that the pressure on the bottom surface of the foundation shall be calculated according to the three action situations of the foundation under axial load \((e=0)\), small eccentric load \((e \leq b/6)\) and large eccentric load \((e > b/6)\). The calculation formula is as follows:

\[
p_k = \frac{F_k + G_k}{A} = \frac{F_k}{A} + \gamma_c d, (e = 0)
\]

\[
p_{k,\text{max}} = \frac{F_k + G_k \pm M_k}{W}, (e \leq b / 6)
\]

\[
p_{k,\text{min}} = \frac{2(F_k + G_k)}{3la}, (e > b / 6)
\]

Where: \(p_k\) is the average pressure value at the bottom surface of the foundation when it is the standard combination corresponding to the action; \(p_{k,\text{max}}\) is the maximum pressure value at the bottom edge of the foundation when corresponding to the standard combination of actions; \(p_{k,\text{min}}\) is the minimum pressure value at the bottom edge of the foundation when corresponding to the standard combination of actions.
combination of actions; \( F_a \) is the vertical force value transmitted from the superstructure to the top surface of the foundation when it corresponds to the standard combination of actions; \( G_b \) is the foundation weight and the foundation soil weight; \( A \) is the basic floor area; \( \gamma \) is the average weight of the foundation and the soil on it; \( d \) is the foundation embedment depth; \( e \) is the distance from the resultant force action point to the centre line of the foundation bottom surface; \( b \) is the width of the foundation bottom surface; \( l \) is the side length of the bottom surface of the foundation perpendicular to the action direction of the moment; \( a \) is the distance from the point of action of the resultant force of the foundation bottom surface to the edge of the maximum pressure of the foundation bottom surface; \( M_b \) is the moment value acting on the foundation bottom surface when corresponding to the standard combination of actions; \( W \) is the resistance moment of the foundation bottom surface.

According to the formulas 1 to 5 are slightly different. There is the possibility of erroneous reference during design and calculation. Attention should be paid to discrimination.

**Article 5.2.5 of the Code for Design of Building Foundation stipulates that when \( b > 3 \text{m} \) or \( d > 0.5 \text{m} \), the characteristic value of foundation bearing capacity determined by load test or other in-situ test, empirical value and other methods shall be corrected according to the following formula:

\[
f_a = f_{ak} + \eta_b \gamma (b - 3) + \eta_d \gamma (d - 0.5)
\]

Where: \( f_a \) is the corrected characteristic value of foundation bearing capacity; \( f_{ak} \) is the characteristic value of foundation bearing capacity determined by load test or other in-situ test, empirical value and other methods; \( \eta_b \) and \( \eta_d \) are foundation bearing capacity correction coefficients of foundation width and embedment depth respectively; \( \gamma \) is the effective gravity of the soil below the foundation bottom; \( \gamma_m \) is the weighted average effective weight of the soil above the foundation bottom; \( b \) is the width of the foundation bottom surface, when the width of the foundation bottom surface is less than 3m, it shall be taken as 3m, and when it is greater than 6m, it shall be taken as 6m; \( d \) is the foundation embedment depth, which should be calculated from the outdoor ground elevation; In the fill levelling area, \( d \) can be calculated from the fill ground elevation, but when the fill is completed after the superstructure construction, \( d \) should be calculated from the natural ground elevation; For basement, when box foundation or raft foundation is adopted, \( d \) is calculated from the outdoor ground elevation; when independent foundation or strip foundation is adopted, \( d \) shall be calculated from indoor ground elevation.

According to the Code for Design of Building Foundation type meets the requirements of foundation bearing capacity, it is usually necessary to carry out joint calculation on formulas (1) to (5). Definitions of parameters \( b, d \) in formulas (1) to (5) are slightly different. There is the possibility of erroneous reference during design and calculation. Attention should be paid to discrimination.

Incorrect Reference of Parameter \( b \): i) Parameter \( b \) incorrectly refers to the width of the short side of the foundation when calculating the sectional resistance moment \( W \) of the foundation bottom surface in formula (2); in the foundation design, in order to reduce the influence of eccentric load and make full use of the foundation resistance bending moment, the long side of the foundation is usually arranged along the eccentric direction of load; in this case, the parameter \( b \) should take the width of...
the long side of the foundation; taking a rectangular foundation as an example, sectional resistance moment \( W = \frac{b^2}{6} \), where \( b \) is the length of the bottom edge of the foundation perpendicular to the direction of bending moment action; it can be seen from formula (2) that when \( b \) takes the long edge of the bottom surface of the foundation, \( W \) value is larger and \( p_k \) is smaller, which is favourable for the foundation to resist bending moment and eccentric load action; ii) Parameter \( b \) in formula (4) and formula (5) is erroneously quoted as the foundation side length in the load eccentric action direction, and parameter \( b \) shall be taken as the foundation short side length; iii) when \( b < 3 \text{m} \), parameter \( b \) in formula (5) is erroneously referenced as \( b = 3 \text{m} \); in fact, only when the local foundation is sandy soil foundation and the width of the foundation is less than 3m can the condition of \( b = 3 \text{m} \) be satisfied.

Incorrect reference of parameter \( d \): in formulas (1) to (3), the self-weight of the foundation and the soil weight above the foundation \( G_k = \gamma_d d \). When the buried depths on both sides of the foundation are inconsistent, \( d \) should take the average value of the buried depths on both sides. In this case, the buried depths on either side are incorrect references, which is different from the value of parameter \( d \) in formula (4).

3. Discussion on the Answer Process of a Registered Civil Engineer (Geotechnical) Examination Question

The registered civil engineer (geotechnical) examination question to be discussed is the 5th question in the morning of 2008. As shown in fig. 1, a brick-concrete residential strip foundation has a homogeneous silty soil with clay content less than 10% and a heavy weight of 19kn/m³. Before construction, the characteristic value of foundation bearing capacity measured by deep load test at the base elevation is 350kpa. It is known that the vertical force transmitted from the upper structure to the top surface of the foundation is 260kn/m, and the average heavy weight of soil on the foundation and steps is 20kn/m³. According to the requirements of the current code for design of building foundation, the design result of foundation width is close \( () \). A. 0.84m, B. 1.04m, C. 1.33m, D2.17m.

At present, the mainstream solutions to the common registered geotechnical examination tutorial materials on the market are as follows [2]:

I) during deep load test:

\[
\eta_d f_a = f_{ak} + \eta_d \gamma_m \left(d - 0.5\right),
\]

\[
350 = f_{ak} + 2 \times 19 \times (5 - 0.5),
\]

Solving equation: \( f_{ak} = 179 \text{kPa} \).

ii) after construction, assuming \( b < 3 \),

\[
f_a = f_{ak} + \eta_b \gamma (b - 3) + \eta_d \gamma_m \left(d - 0.5\right)
\]

\[
f_a = 179 + 0.5 \times 19 \times (3 - 3) + 2 \times 19 \times (2 - 0.5) = 236 \text{kPa}
\]

iii) \( b = \frac{F_s}{f_a - \gamma_G d} = \frac{260}{236 - 20 \times 2} = 1.33 \).

The process of solving problems in the first and second steps above violates the precondition of applying formula (4), that is, when the characteristic value of local foundation bearing capacity is determined by deep plate load test, the correction coefficient \( \eta_d \) of embedment depth is 0.
For homogeneous soil foundation, it is assumed that the shallow plate load test and the deep plate load test are respectively carried out at the elevation of the foundation bottom surface, and the uncorrected characteristic values of foundation bearing capacity are $f_{ak1}$ and $f_{ak2}$, respectively. When the characteristic value of the bearing capacity of the local foundation is determined by the deep plate load test, the depth correction coefficient $\eta_d$ is taken as 0, and the formula (4) is as follows:

$$f_{a2} = f_{ak2} + \eta_b \gamma (b - 3)$$

(6)

$$f_{a1} = f_{ak1} + \eta_b \gamma (b - 3) + \eta_d \gamma d (d - 0.5)$$

(7)

Both sides of the equal sign in equations (6) to (7) simultaneously calculate partial derivatives for $d$, which shows that

$$\frac{\partial f_{ak2}}{\partial d} = \frac{\partial f_{a2}}{\partial d} = \frac{\partial f_{a1}}{\partial d} = \eta_d \gamma$$

(8)

The correct solution to the above question is as follows:

i) carrying out depth correction on the characteristic value $f_{ak}$ of the foundation bearing capacity determined by the deep plate load test at the elevation of the foundation bottom surface:

$$f_{ak} = f'_{ak} - \frac{\partial f'_{ak}}{\partial d} \times (d_1 - d_2),$$

$$f_{ak} = 350 - 2 \times 19 \times (5 - 2) = 236 \text{kPa},$$

ii) apply formula (4) to modify the characteristic value $f_{ak}$ of foundation bearing capacity:

$$f''_{ak} = f''_{ak} + \eta_b \gamma (b - 3) = 236 + 0.5 \times 19 \times 0 = 236 \text{kPa},$$

iii) $b = \frac{F_i}{f''_{ak} - \gamma \gamma d} = \frac{260}{236 - 20 \times 2} = 1.33.$

Although the answers of the above two methods are the same, the second method is obviously more reasonable in calculation principle.

4. Conclusions

Article 5.2 of the Code for Design of Building Foundation gives the calculation formula of foundation bearing capacity. Some parameters in the calculation formula have the same symbols in front and back references, while the meanings represented by the parameters are different, resulting in the possibility of misuse by designers in the actual application process. According to the principle of soil mechanics, this paper discusses the confusing values of some parameters in the calculation formula of foundation bearing capacity, the main conclusions are as follows:

1) when designing foundation, in order to reduce the influence of eccentric load and give full play to the function of foundation resisting bending moment, the long side of foundation is usually arranged along the eccentric direction of load. When calculating the resistance moment $W$ of foundation bottom surface, parameter $b$ is easy to misquote the short side width of foundation. The correct method is to select the long side width of foundation.

2) when determining the characteristic value of foundation bearing capacity according to the shear strength index of soil, only the local foundation is sandy soil foundation, and when the foundation width is less than 3m, the parameter $b$ is 3m.

3) By discussing the problem-solving process of the 5th question in the morning of 2008 in the registered civil engineer (geotechnical) professional examination, it is concluded that the characteristic value $f_{ak}$ of foundation bearing capacity determined from the deep plate load test of homogeneous soil...
foundation is satisfied \( \frac{\partial f_{ak}}{\partial d} = \eta_d \gamma' \), and the basic assumption premise must be satisfied when the formula is applied.

Acknowledgments
In the process of reviewing the registered geotechnical engineers preparing for the examination, the author found that the definition and explanation of some parameters of the foundation bearing capacity calculation formula in the code for design of building foundation are not detailed, which is easy to cause misunderstanding. Therefore, the author came up with the idea of writing this paper, hoping to be helpful to the geotechnical designers. In addition, further discussion by mail is also welcome!

References
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[2] Zeng, L. (2019) National Certified Geotechnical Engineer Qualification Examination: One Professional Case for All [M], Guangdong Tourism Publishing House, Guangzhou.