Discussion on Calculation Method of Soft Soil Foundation Settlement in Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract: The modulus of compressibility of muddy soil in Dawan District is low, and the equivalent value of modulus of compressibility within the calculated depth range of foundation settlement is generally less than 2.5MPa, which exceeds the value range of empirical coefficient calculation basis for settlement calculation in the specification, and has the characteristics of large settlement. This time, according to the measured data of a coastal foundation settlement in Dawan District, the maximum settlement is fitted with the hyperbolic method, and the theoretical value of the total settlement is calculated according to the Code for Design of Building Foundation (GB50007-2011). Based on this analysis, the fitting curve equation of the empirical coefficient of settlement calculation when the equivalent value of the compression modulus is 2.5~4.15MPa is given, and the recommended value of the empirical coefficient of settlement calculation when the equivalent value of the compression modulus is 1.5~2.5MPa is calculated, so as to improve the calculation deviation of the original formula.

1.Introduction

Guangdong Hong Kong Macao Greater Bay Area (GBA) [7] With the promotion of the construction of the Great Bay Area in Guangdong, Hong Kong and Macao, the problem of the silt soft soil foundation engineering in the Great Bay Area is becoming increasingly prominent. The main terrain of the Great Bay Area is muddy terrain, which is composed of fine particles such as silt and silt with a gentle slope. Among them, silt is developed in areas with rich sediment supply [6] and weak tidal current carrying capacity. Due to the weak energy of waves passing through shoals and the active tidal action, a large range of muddy terrain is developed here. From the perspective of agriculture and animal husbandry, the fertile soil of silt is often developed into a good place for beach aquaculture [10], but it is just the opposite for engineering construction [8]. Therefore, it is necessary and urgent to develop the treatment of muddy soft soil foundation. In this paper, the calculation experience coefficient is modified through the building foundation design code to reduce the calculation deviation, so as to ensure that the foundation treatment design is more realistic to reduce engineering accidents caused by design problems.

In engineering design, the purpose of settlement calculation is to avoid damage to the main structure of the building due to settlement, affect the normal use of the building, and cause huge economic losses. [9] However, in view of the low shear strength, high compressibility, low permeability, large natural water content and other characteristics of mucky soil, the calculation error of general foundation settlement formula on mucky soil is large. [1] Therefore, it is necessary to summarize the calculation experience coefficient for the characteristics of soft soil in Dawan District through the settlement data laws of actual projects. In this paper, the classic layered summation method or the method recommended by the specification is used to calculate the final settlement; The relationship between settlement and time is calculated by field measured data (this method has a certain theoretical basis and a simple operation method, such as graphical solution [5]).

2. Project Facts

2.1 Geographic location

The project site is located in the north of Huandao East Road in the northeast corner of Hengqin New District, Zhuhai, and in the northeast of Yanghuan Village. During the survey, the measured elevation of each borehole orifice changed from -1.48 to 4.16 meters. The foundation is treated by vacuum combined with surcharge preloading.

2.2 Formation lithology

According to the drilling results, the buried strata in the

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site mainly include artificial fill, Quaternary marine terrestrial sedimentary layer and eluvium, and the underlying bedrock is Yanshanian granite. The strata developed in the site are described from top to bottom as follows: 2.2.1 Filling soil (Q^{ml}) ①, Quaternary marine terrestrial sedimentary layer (Q^{mc}): this layer consists of silt ②- 1, coarse sand ② - 2, clay ② - 3, coarse sand ② - 4, muddy clay ② - 5, clay ② - 6 and gravelly sand ② - 7; Quaternary granite eluvium sandy clay (Q^{el}) ③ and Yanshanian (γ_y) Granite④.

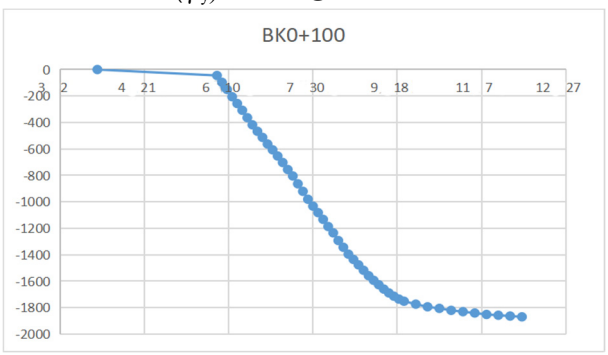

Figure 1 BKO100 Hole Settlement and Time Curve

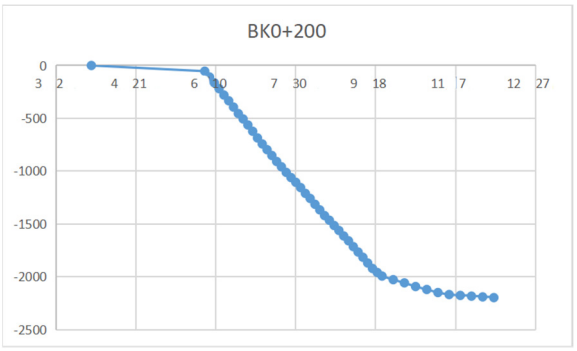

Figure 2 BKO200 Hole Location Settlement and Time Curve

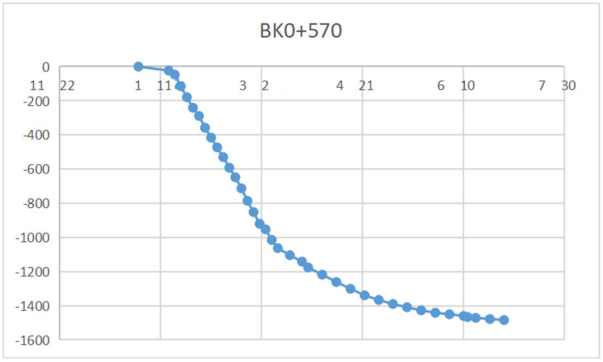

Figure 3 BKO570 Hole Settlement and Time Curve

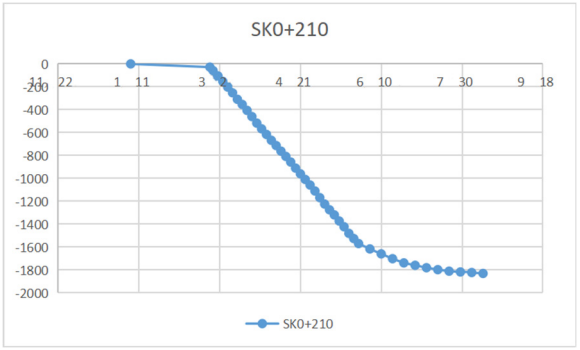

Figure 4 Settlement and Time Curve of SKO210 Borehole

3.Settlement calculation

The formula in the Code for Design of Building Foundation is used to calculate the foundation settlement [3]:

$$S = \psi_S S' = \psi_S \sum_{i=1}^{n} \frac{p_c}{E_{si}} (z_i a_i - z_{i-1} a_{i-1}) \quad (1)$$

S: Final deformation of foundation (mm); S ′: foundation deformation calculated by layer summation method (mm); ψ_s: Empirical coefficient for settlement calculation; n: Number of soil layers divided within the calculated depth range; P_c: additional pressure at the bottom of the foundation corresponding to the quasi permanent combination of load effects (kPa); E_{si}: compression modulus of the ith layer of soil under the foundation bottom (MPa).

The calculated settlement relationship of each hole is as follows:

2.3 Settlement Monitoring Results

The monitoring scheme shall be arranged according to the distribution and thickness of soft soil layer on site. The observation of 4 observation points lasted for about 282 days. Due to the thick soft soil layer, a settlement magnetic ring was set at the boundary of the soil layer. The observation results are as follows (The monitoring data of a embankment in Zhuhai is quoted):

Table 1 Settlement of Each Hole

Hole location	BKO100	BKO200	BKO570	SKO210
Theoretical alculated	1651.729843	2030.625601	1355.390958	1630.912236
settlement	-1870	-2198	-1484	-1830

4.Calculation of settlement

In this paper, the hyperbolic model based on three-point method is used to predict the maximum settlement [2].

The basic equation of the hyperbolic model is:

$$S_t = S_0 + \frac{t - t_0}{\alpha + \beta(t - t_{0)}} \quad (2)$$

Formula 2: So is the settlement at time to; St is the settlement at time t; α.β All are undetermined parameters. Write equation (2) as a diagram:

$$\frac{t-t_0}{S_{t-}S_0}=\alpha+\beta(t-t_0) \tag{3}$$

From the above formula, α.β They are the intercept and slope in the relation, which can be solved by graphical method: Substitute the calculated values of a and B into equation (2), and the decrement S and the final decrement at any time t can be obtained.

It can be seen that α.β Calculation formula of:

$$\begin{cases}\alpha=\dfrac{(S_3-S_2)(t_3-t_1)(t_2-t_1)}{(S_3-S_1)(S_2-S_1)(t_3-t_2)}\\ \beta=\dfrac{(t_3-t_1)(S_2-S_1)-(t_2-t_1)(S_3-S_1)}{(S_3-S_1)(S_2-S_1)(t_3-t_2)}\\ S_\infty=S_1+\dfrac{2(S_3-S_2)(S_2-S_1)}{(S_2-S_1)(S_2-S_2)}\end{cases} \tag{4}$$

According to the measured settlement data, select t=148d as the inflexion point of the curve for SKO210 hole to predict the settlement, and draw:

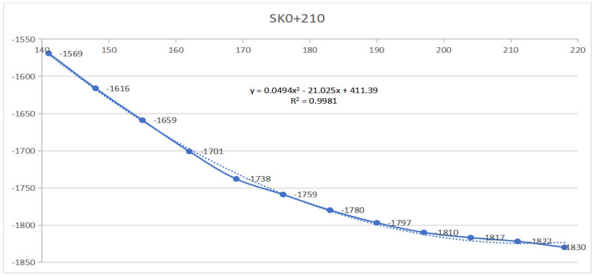

Figure 5 Fitting curve of SKO210 hole settlement change with time

Three groups of (t, s) values after settlement stabilization are selected from the s-t curve for calculation, and the average values of settlement results of other hole numbers are shown in the table.

Table 2 average settlement of each hole

Hole location	SK0210	BKO570	BKO200	BKO100
S∞	1861.39	1329.65	2191.49	1990.96

5. Comparison of forecast results

The relationship between the three groups of average values (S average) of each hole and the theoretical deformation (S ′) is calculated respectively. The comparison table of S flat and S ′ is as follows.

Table 3 Comparison of S average and S'

Hole location	BKO200	BKO100	SK0210	BKO570
Forecast average (S average)	2191.49	1990.96	1861.39	1329.65
Theoretical deformation (S ′)	2030.625601	1651.729843	1630.912236	1355.390958
$S_{Average}/S'$	1.079219133	1.205378718	1.141318312	0.981008463

6. Calculation of empirical coefficient for settlement calculation

The settlement empirical coefficient is given in the Code for Design of Building Foundation ψ' The recommended value of, because the range of Es is limited, that is, when Es<2.5MPa, the empirical coefficient of settlement is not given. Therefore, the empirical coefficient of compression modulus based on engineering examples ψ' To calculate the value of [7]

$$\overline{Es}=\frac{\sum Ai}{\sum\frac{Ai}{Esi}} \tag{5}$$

In Formula 5, Ai is the additional stress area of layer i soil; $A_i=p_o=(z_i\alpha_i-z_{i-1}\alpha_{i-1})$, E_{si} is the compression modulus of the ith layer corresponding to $p_{1i}\sim p_{2i}$section, and the relationship between the hole number S flat/S ′ and the equivalent value of the compression modulus ($\overline{Es}$) [3].

Table 4 $S_{Average}/S'$- $\overline{Es}$ Table

Hole ocation	BKO200	BKO100	SK0210	BKO570
$\overline{Es}$	2.044332586	2.2801243	2.106431765	1.943511282
$S_{Average}/S'$	1.079219133	1.205378718	1.141318312	0.981008463

As Es of the four hole locations are less than 2.5MPa, the fitting of S flat/S ′ and is shown in Figure [11] [4] based on the engineering example, R^2=0.9302, so the fitting is feasible, and the fitting equation is: ψ_s=0.4316Es^1.2673(2.05≤Es≤4.15)

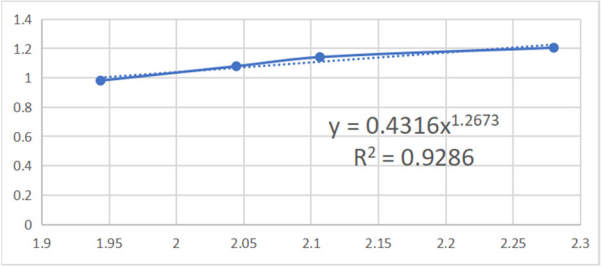

Figure 6 $\overline{Es}$ - Saverage/S ′ fitting curve

7. Conclusion

In this paper, the differences in settlement calculation of muddy soil in Dawan District are corrected in various ways, and the following conclusions are given:

(1) According to the actual monitoring data, the empirical coefficient fitting curve equation of settlement calculation is calculated when the equivalent value of compression modulus is within the standard range of Code for Design of Building Foundation (GB50007-2002).

(2) The recommended value of empirical coefficient for settlement calculation is calculated when the equivalent value of modulus of compressibility in Dawan is 1.5 ~ 2.5 MPa.

(3) When calculating the settlement of soft soil foundation, the hyperbolic method is used in this paper to compare the theoretical calculation, so as to improve the accuracy of the calculation.

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