BASEMENT DEFORMATION OF MULTI-STORY DWELLING WITH COMPOSITE PILE FOUNDATION

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Abstract

This paper presents several groups of monitoring settlement for composite pile foundation of dwelling in soft soil region in China. Compared with settlement of calculation according to "Foundation Design Code"(BGJ08-11-1999), a real settlement of a composite pile foundation is much less than calculation values. Authors analyze the main reasons for error between monitoring value and calculation value. And a reasonable calculation method has been provided. The calculation method can be used in coming dwelling design in soft soil region.

1. Introduction

With the development of city building after China was open its door in the late of 1970s, many high-rise buildings and underground tunnels for transportation and various pipes have been built. This gave rise to environment protection problem of old building, especially for dwelling with shallow foundation built in soft soil from 1950s to 1980s. Therefore, at the end of 1990s, shanghai construction committee issued a file. The file demands that the total settlement for dwelling in Shanghai must be not more than 150mm and that eccentric distance is not more than 15‰. Based on this rule, most of all dwelling in Shanghai need to put small size piles in soft soil in order to control settlement. But through study for several years and experience, we find that settlement of calculation according to foundation design code (GBJ08-11-1999) is much larger than that of monitoring.

2. The steps of calculation settlement

2.1 Settlement of pile itself

On the basis of Mindlin stress formula, total settlement of pile foundation for entire layer can be given as:

$$s = \psi_m \sum_{t=1}^{T} \frac{1}{E_{s,t}} \sum_{i=1}^{n_t} \sigma_{z,t,i} \Delta H_{t,i} \tag{1}$$

$$\sigma_z = \frac{Q}{L^2} \sum_{j=1}^{k} [\alpha I_{p,j} + (1-\alpha) I_{s,j}] \tag{2}$$

where

s—total settlement

ψ_m —experience coefficient for pile foundation settlement calculation

T—total stratum number from the bottom of pile to the bottom of compression zone depth according to geological survey report

$E_{s,t}$ —modulus of compression in the number t stratum when it is acted by self-weight stress and self-weight plus superimposed stress

n_t—total number for calculation in the number t stratum

$\sigma_{z,t,i}$ —vertical superimposed stress of number i sublayer in the number t stratum from the bottom of pile

$\Delta H_{t,i}$ —thickness of sublayer i in the number t stratum from the bottom of pile

Q—calculation load for a single pile(unit:kN), the load should be an average superimposed load corresponding to the load in a long term effect combination

L—length of pile

k—total number of pile

α —ratio of resisting force in the end of pile to settlement calculation load

$I_{p,j}$, $I_{s,j}$—stress effect coefficient in the stress calculation point of the number j pile, for the end of pile and for the lateral surface of pile respectively

2.2 Settlement of pile cap

The total settlement of pile cap for entire layer can be given as:

$$s = \psi_s b p_0 \sum_{i=1}^{n} \frac{\delta_i - \delta_{i-1}}{(E_{s,0.1\sim0.2})_i} \tag{3}$$

where

s — total settlement (unit: mm)

ψ_s —settlement coefficient

b —width of pile cap

p_0 — superimposed pressure in the bottom of pile cap corresponding to the load in a long term effect combination (unit: KPa)

i —the number i sublayer from the bottom of pile cap to the bottom of compression zone depth

δ_i , δ_{i-1} — settlement coefficient of the number i sublayer and i-1 sublayer respectively

$E_{s,0.1\sim0.2}$— modulus of compression when the soil is acted by 0.1~0.2 MPa pressure.

2.3 The total settlement

If $P - \sigma_c A_c > kR_k$,then total settlement for a point of a dwelling is equal to settlement of pile plus settlement of pile cap.

where

σ_c —self-weight stress in the bottom of pile cap

A_c— total area of pile cap

P—total load of long term effect combination at the bottom of pile cap

k— total number of pile

R_k—ultimate bearing capacity of a single pile

If $P - \sigma_c A_c \le kR_k$,then total settlement for a point of a dwelling is equal to settlement of pile.

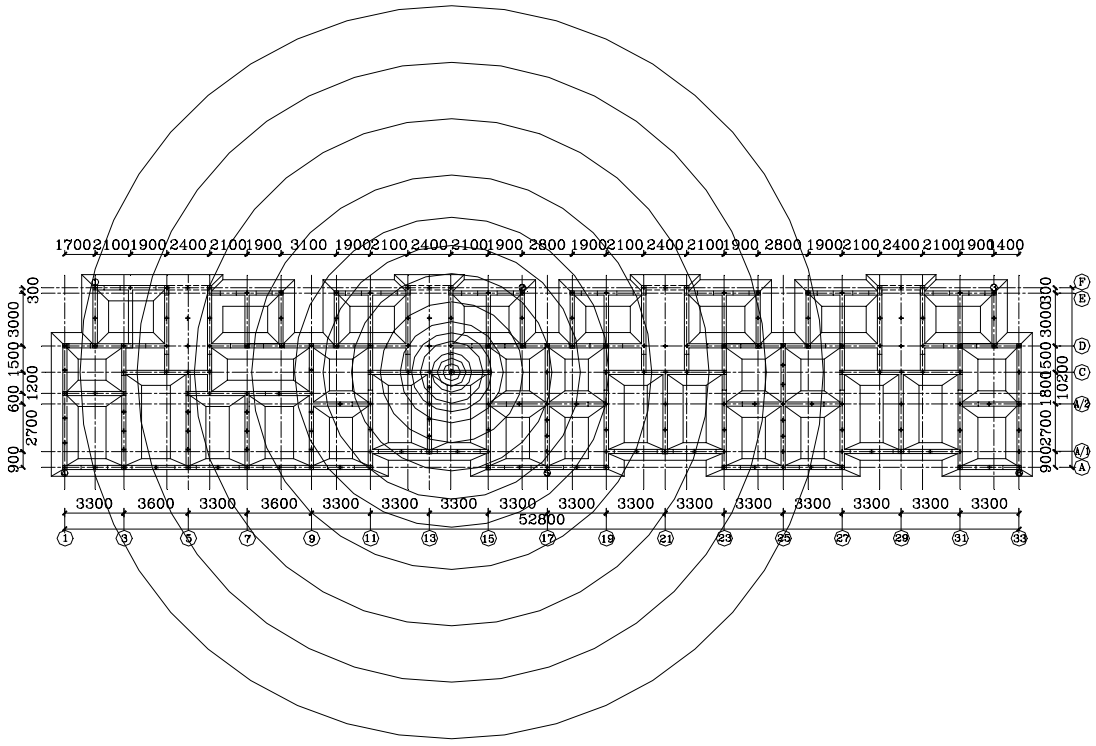
3 The results of calculation and monitoring for dwelling

3.1 The dwelling introduction

The dwelling, which is a six-story brick-and-concrete composite construction in soft soil, was built in 1999. It consists of four units and every unit has two flats. Its floor height is 2.8 meters. The total height is 16.8 meters. The total width is 10.2 meters. In this dwelling, 262 piles which is 16 meters long and its section dimension is 200mm*200mm. The end of pile is located in □ 2 stratum named gray silt soil with sand which modulus of compression is 7.62Mpa.

3.2 The settlement of calculation and monitoring

Based on the load code, the total design load of superstructure is 52340kN. Through influence chart and piling plan, shown in figure 1 and forum (1) and (2), settlement in every point can be calculated. The result is shown in table 1.



+—pile, o—monitoring point

Figure 1 influence chart and piling plan and monitoring points

Table 1 calculation settlement

Point	1	2	3	4	5	6	Average settlement of these six points is 92mm
Settlement(mm)	82	115	83	80	110	81	

*average settlement of whole dwelling is 101mm.

During the construction and in one year after it was built, from May in 1999 to December in 2000, the every point in the table 1 has been measured with the help of grade S1 leveling instrument. The result in December of 2000 year is shown in table 2.

Table 2 monitoring settlement

Monitoring point	1	2	3	4	5	6	Average settlement of these six points is 15mm
Settlement(mm)	17.0	17.8	17.7	11.6	11.9	12.7	

Generally, total settlement of a multi-story building in soft soil region is three times that of the first one and a half year from the date when the building begin to finish its foundation. According to this experience, the total settlement above example should be about 45mm. There are big error between calculation value and real monitoring value.

Here there are some other examples for supporting the fact that calculation value is much more than real value for multi-story dwelling with composite pile foundation, shown in table 3.

Table 3 settlement of two multi-story dwelling in soft soil region

The number of dwelling	1	2	3	4	5
Total average settlement of calculation (mm)	102	110	115	130	108
Accumulative settlement of monitoring (mm)	11	15	16	16	12

*accumulative settlement of monitoring is measured from the dwelling of foundation having been finished to one year after the dwelling was built.

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4 The reasons of difference between calculation and monitoring

4.1 According DBJ08-11-1999, if $P-\sigma_c A_c > kR_k$, settlement consists of two parts. One is caused by pile load and the other is caused by pile cap. In fact, the settlement caused by pile is the same as that of pile cap because of coordination deformation between the bottom of pile cap and the top of pile.

4.2 The load in calculation is the long-term load effect combination value. Actually the load of monitoring is less 0.25 times than calculation value.

5 Conclusion

It is suggested that total settlement is equal to average pile settlement or pile cap settlement when the pile settlement is the same as pile caps displacement. Thus the calculation value will be more near real value. Furthermore, we can reduce the number of pile with this suggestion in coming design of multi-story dwelling when its total settlement is less than 150mm.

In order to improve calculation method, we can edit computer programme to adjust the pile number and area of pile cap till settlement of pile is equal to that of pile cap.

References

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