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Determination of Silty Soil Bearing Capacity in Binzhou China

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Abstract: The characteristical values of bearing capacity of silty soil are determined on different basis in Binzhou area, which causes a great difference in actual work. Based on engineering practices, most original data are counted and calculated for standard penetration test, soil test and double bridge CPT (cone penetration test). The result shows that the bearing capacity is more accurate as concluded by *in-situ* test data, and also can provide a more helpful method for foundation design, which will play an active role in undertaking the specific engineering investigation work and maintaing the summary of regional emperical values.

Keywords: Binzhou area, characteristical values of bearing capacity, *in-situ* test, silty soil.

1. INTRODUCTION

There widely distributed is the Yellow River alluvial formation and paralic sediment with large deposition thickness in Binzhou area. The silty soil is widespread with 0 -7.5 m depth and 0.5-6.2 m thickness, and can always act as a bearing layer for buildings. To determine the bearing capacity of the silty soil, both special standard penetration test data and soil test data were used. However, there existed obvious difference between the above two calculated results [1-3], causing a certain degree of interference for foundation design. Therefore, to provide more accurate basis for foundation design, and find more practical regional experience values, the authors applied the specific statistical analysis [4] to scientifically determine the bearing capacity of the silty soil.

2. BASIC CHARACTERISTICS OF SILTY SOIL IN BINZHOU AREA

674 drilling data of engineering investigation projects were chosen from four representative power plants, for civil and industrial construction in Binzhou area, where the silty soil mainly sedimented in alluvial formations. The overall characteristics are as follows:

Silty soil (Q_4^{al}), brown to dark brown, slightly tight - close grained, slightly wet - very wet, 0.5- 6.2 m thickness. The physical and mechanical parameters are shown in Table **1**.

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3. METHODS FOR DETERMINING BEARING CAPACITY

3.1. Determining Bearing Capacity of Silty Soil by Standard Penetration Test

3.1.1. Standard Penetration Test Data Statistics

Standard penetration tests were performed for 181 times in the silty soil sediment. The results are shown in Table **2**.

3.1.2. Calculation and Analysis of Statistical Data

According to the statistical results, data distribution histogram (see Fig. **1**) is shown as follows:

From the results of the statistics mentioned in Fig. (**1**), standard penetration number mainly concentrated in the range from 3 to 6, which was about 88.9% of the total statistical data, and the proportion of 2, 7, 8 and 9 is less comparative. After calculating these data, according to the related literature [5], the variation coefficient δ= 0.317, which is greater than the theoretical upper limit value of 0.3. If the numbers of 2, 7, 8, 9 are eliminated for obvious deviation, the variation coefficient δ=0.239 < 0.3 (the theoretical upper limit value of variation coefficient), then the standard value Φ_k=4.215, maximum value 6, minimum value 3 and average value Φ_m=4.356.

3.1.3. Calculating Characteristical Value of Bearing Capacity

As it was mainly alluvial plains of the Yellow River in Binzhou area, and the silty soil sediment was mainly alluvial origin [6], we refered to Technical Standard for Building Foundation (DB42/242-2003) and Base Design Criterion of Construction Foundation (DBJ15-31-2003) [7, 8], where

Table 1. **Physical and mechanical parameters statistics.**

Geotechnical Name	Statistical Projects	Natural Water Content w (%)	Specific Gravity of Soil Gs	Natural Void Ratio e	Liquid Limit wL (%)	Plastic Limit wp(%)	Liquidity Index IL
Silty soil	Statistical number	117	120	114	120	120	83
	Max	46.2	2.76	1.319	51.9	30.3	1.15
	Min	16.7	2.67	0.481	21.8	14	0.33
	Average	25.4	2.7	0.72	29.8	19.1	0.65
	Standard value	26.3	2.7	0.747	28.9	18.7	0.68
	Standard deviation	5.797	0.019	0.168	5.712	2.535	0.175
	Coefficient of variation	0.228	0.007	0.233	0.192	0.133	0.27

Table 2. **Collected data of standard penetration test in field.**

Blow Count(blow)	2	3	4	5	6	7	8	9
times	4	45	37	55	24	9	2	5

Table 3. **Statistical result of natural water content data.**

Natural Water Content	15≤W<20	20≤W<25	25≤W<30	30≤W<35	35≤W<40	40≤W<45	45≤W<50
number	8	71	29	14	15	8	3

causes of silty soil sediment are similar，which provides experience tables for characteristical value of bearing capacity. The characteristical value is 129.3 kPa obtained by interpolation method.

3.2. Determining Bearing Capacity of Silty Soil by Soil Test Data

3.2.1. Determining Standard Value of Natural Water Content
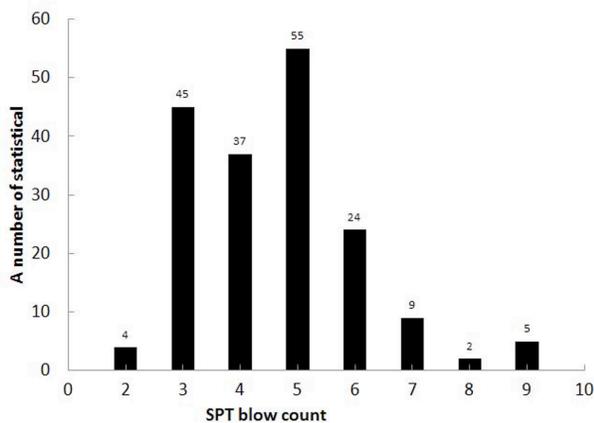

Fig. (1). Standard penetration test blow count and statistical times.

3.2.1.1. Natural Water Content Data Statistics

148 natural water content data obtained from practical engineering got counted according to the distribution range. The results are shown in Table **3**.

3.2.1.2. Calculation and Analysis of Statistical Data

Using the statistical results, data distribution histogram (see Fig. **2**) is performed.

From the above statistical results, natural water content (w) data concentrated mainly in the range of 20%~40%, that was about 87% of total data. If w < 20% or w > 40%, the proportion would be smaller. Based on statistical analysis of the above data, the variation coefficient δ is 0.254, which is greater than the theoretical upper limit value 0.15. If data of w < 20% or w > 40% deviating extensively is eliminated, variation coefficient δ is 0.148, which is less than 0.15. Then, the standard value Φ_k is 24.24, maximum value 31.4, minimum value 20.2, and average value $\Phi_m = 24.84$.

3.2.2. Determining Natural Void Ratio Standard Value

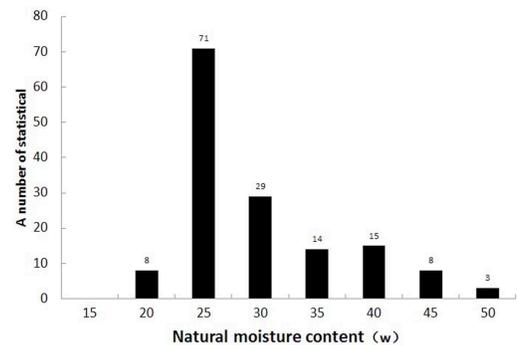#### 3.2.2.1. Statistics of Natural Void Ratio Data

Fig. (2). Statistical histogram of natural water content distribution and number.

136 natural void ratio data obtained from practical engineering got counted according to the distribution range. The results are shown in Table **4**.

3.2.2.2. Calculation and Analysis of Statistical Data

Using the statistical results, data distribution histogram (see Fig. **3**) was performed.
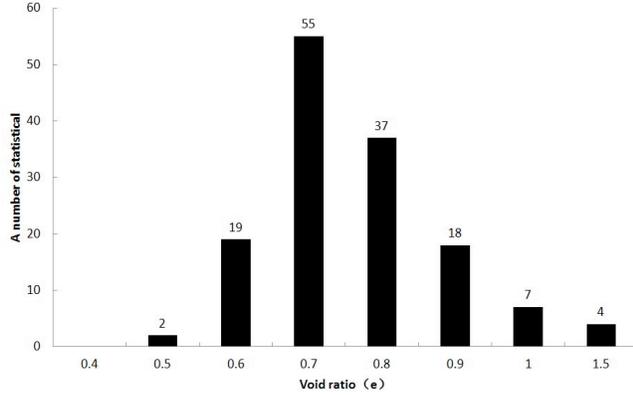

Fig. (3). Statistical histogram of natural void ratio distribution and number.

From the above statistical results, natural void ratio (*e*) data concentrated mainly in the range of 0.5~0.9, that is about 90.8% of the total data. If e < 0.5 or e >0.9, the proportion is smaller. Based on the statistical analysis of above data, the variation coefficient δ is 0.202 without deviating any data, which is greater than the theoretical upper limit value 0.15. If data of e < 0.5 or e > 0.9 deviating extensively is eliminated, variation coefficient δ is 0.117, which is less than 0.15. Then, the standard value Φ_k is 0.688, maximum value 0.889, minimum value 0.505, and average value Φ_m =0.698.

3.2.3. Calculating the Characteristical Value of Bearing Capacity

According to the above standard data of natural water content and natural void ratio, referring to Technical Specification for Building Foundation (DB42/242-2003) and Base Design Criterion of Construction Foundation (GB 50007-2002) [9], the characteristical value of bearing capacity being 198.2 kPa was obtained by interpolation method.

3.3. Determining Bearing Capacity of Silty Soil by Double Bridge CPT

3.3.1. Statistics of Double Bridge CPT (Cone Penetration Test) Data

1095 double bridge CPT data obtained from practical engineering were counted according to the distribution range. The results are shown in Table **5**.

3.3.2. Calculation and Analysis of Statistical Data

Using the statistical results, data distribution histogram (see Fig. **4**) was performed.

From the above statistical results, cone tip resistance (q_c) data concentrated mainly in the range of 0.75-2.0, about 86.5% of total data. If q_c < 0.75 or q_c > 2, the proportion is smaller. Based on the statistical analysis of above data, the variation coefficient δ is 0.617, which is greater than the theoretical upper limit value of 0.3. If data of q_c < 0.75 or q_c > 2 deviating extensively is eliminated, variation coefficient δ is 0.267, which is less than 0.3. Then, the standard value Φ_k is 1.367, maximum value 2, minimum value 0.76, average value Φ_m =1.386 and data number n = 918.

3.3.3. Calculating Characteristical Value of Bearing Capacity

Referring to Technical Standard for Building Foundation (DB42/242-2003) and Base Design Criterion of Construction Foundation (DBJ15-31-2003), the characteristical value of bearing capacity is 134.2 kPa obatined by comprehensive method.

4. DETERMINATION OF BEARING CAPACITY OF SILTY SOIL

According to the standard penetration test, soil test and double bridge CPT, comparative analysis result of bearing capacity was shown in Table **6**.

Table 4.　Statistical result of natural void ratio data.

Void Ratio	e<0.4	0.4≤e<0.5	0.5≤e<0.6	0.6≤e<0.7	0.7≤e<0.8	0.8≤e<0.9	0.9≤e<1.0	e>1
Number	0	2	19	55	36	13	7	4

Table 5.　Cone tip resistance data collection.

Cone Tip Resistance	qc<0.5	0.5≤qc<0.75	0.75≤qc<1	1≤qc<1.25	1.25≤qc<1.5	1.5≤qc<1.75	1.75≤qc≤2	q c>2
Number	43	47	207	223	190	174	153	58

Table 6.　Comparative analysis result of bearing capacity.

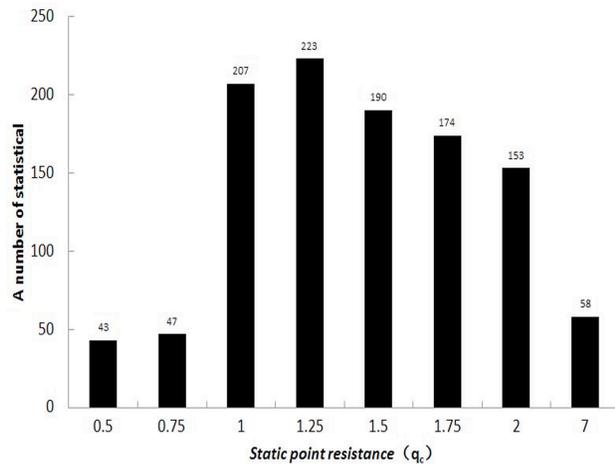| Method	Standard Penetration	Soil Test	Double Bridge CPT
characteristic value of bearing capacity (kPa)	129.3	198.2	134.2

Fig. (4). Statistical histogram of cone tip resistance and number.

From the above table, the two characteristical values of bearing capacity calculated by standard penetration method and double bridge CPT method trun to conincide with each other better, so the proposed characteristical value of bearing capacity of silty soil is 130kPa. The recommended value is closer to the regional current empirical value of 100~130kPa. However, the value of soil test is bigger than 50kPa.

CONCLUSION

The study calculated the bearing capacity of silty soil through the standard penetration test and double bridge CPT. However, the test data differ greatly by using the soil results.

Characterical value of bearing capacity was determined through the standard penetration test. The double bridge CPT of these *in-situ* test showed it was coincided well with the present regional empirical value. In Binzhou area, the characterical value of the bearing capacity of the silty soil was suggested to be 130kPa.

For the silty soil sediment in Binzhou area, we should pay more attention to *in-situ* test methods of standard penetration test and double bridge CPT. Especially, when determining characteristical value of bearing capacity, *in-situ* test data should be focused on, so that the calculated value can reach more accuracy.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

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