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The Open Civil Engineering Journal, 2015, *9*, 877-880

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Determination of Silty Soil Bearing Capacity in Binzhou China

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Abstract: The characteristic values of bearing capacity of silty soil are determined on different basis in Binzhou area, which causes a greater difference in actual work. Based on engineering practices, a plenty of original data are counted and calculated according to standard penetration test, soil test and double bridge CPT in order to be analyzed and compared. The results show that the bearing capacity obtained from the field test data is more accurate. Standard penetration test and double bridge CPT match better to determine the bearing capacity of the silty soil. The eigenvalues of bearing capacity of silty soil is suggested to be 130kPa. Standard penetration test and double bridge CPT should be paid more attention to the silty soil sediment in Binzhou area in the investigation work.

Keywords: Binzhou area, characteristic values of bearing capacity, *in-situ* test, silty soil, CPT, Standard penetration test.

1. INTRODUCTION

The Yellow River alluvium and sediments in Binzhou area have a large thickness and a wide range. The silty soil distributes widely, with 0 -7.5m depth and 0.5-6.2m thickness, usually used as a bearing layer for buildings. To determine the bearing capacity of this layer, some technicians use the standard penetration testing data, while others use soil testing data. But there is a clear difference between these two results [1-3], causing a certain degree of interference for foundation design. Therefore, specific statistical analysis [4] was applied to scientifically determine the bearing capacity of silty soil, which provided a more accurate basis for foundation design and found more practical and feasible local empirical value.

2. BASIC CHARACTERISTICS OF SILTY SOIL IN BINZHOU AREA

The data of 674 boreholes in four power plants, obtained in the construction of large engineering investigation project, are selected for study and they have extensive representation. The silt layers in this area are alluvium, and the overall characteristics are as follows:

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Silty soil (Q_4^{al}) is 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**.

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 are performed for 181 times in the silty soil sediment. The statistical results are shown in Table **2**.

3.1.2. Calculation and Analysis of Statistical Data

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

From the results of the statistics mentioned in Fig. (**1**), the results of standard penetration test mostly concentrate in the range of 3~6, accounting for 88.9% of the total statistics. The proportion of 2, 7, 8 and 9 is a bit less. After calculating these data, according to the related literature [5], the variation coefficient δ= 0.317, which is greater than the theoretical upper limit of 0.3. If numbers of 2, 7, 8, 9 are eliminated for their 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.

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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

3.1.3. Calculating Characteristic Value of Bearing Capacity

Because Binzhou area is mainly located in the Yellow River alluvial plain, silty soil sediments are mostly caused by alluvial deposits [6]. According to the empirical value of Technical Standard for Building Foundation (DB42/242-2003) and Base Design Criterion for Construction Foundation (DBJ15-31-2003) [7, 8] in which the formation reasons of silty soil sediment are similar to Binzhou area , the characteristic value of bearing capacity is 129.3 kPa obtained by interpolation.

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

3.2.1. Determining Standard Value of Natural Water Content

3.2.1.1. Natural Water Content Data Statistics

148 natural water content data obtained from the actual project are counted according to the distribution interval, and the statistical results are shown in Table **3**.

3.2.1.2. Calculation and Analysis of Statistical Data

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

From the above statistical results, natural water content (w) data mainly concentrate in the range of 20%~40%, accounting for about 87% of the total statistical data. The ratio of w <20% and w> 40% is smaller. Based on the statistical analysis of the above data, the coefficient of variation δ is 0.254, which is larger than the theoretical upper limit of 0.15. If the data of w <20% and w> 40% are eliminated for their obvious deviation, the variation coefficient δ=0.148 < 0.15 (the theoretical upper limit value of variation coefficient), then the standard value Φ_k is 24.24, maximum value 31.4, minimum value 20.2, the average value of Φ_m = 24.84.

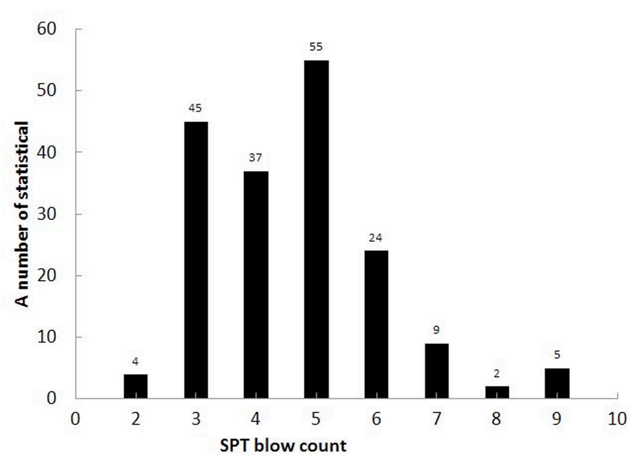

Fig. (1). Number of blows and statistical times of Standard penetration test.

3.2.2. Determining Natural Void Ratio Standard Value

3.2.2.1. Statistics of Natural Void Ratio Data

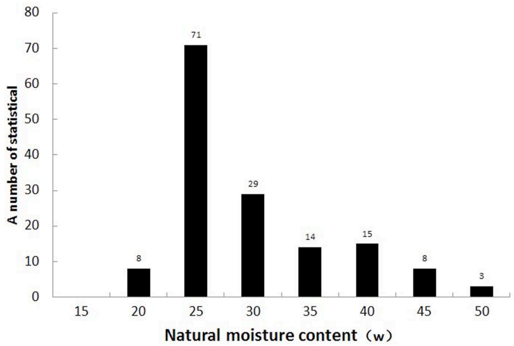

Fig. (2). Statistical histogram of natural water content distribution and number.

According to the distribution of 142 natural void ratio obtained from the actual project, the statistical results are shown in Table **4**.

3.2.2.2. Calculation and Analysis of Statistical Data

Using the statistical results, a data distribution histogram is performed (Fig. **3**).

From the above statistical results, natural void ratio (*e*) data mainly concentrate in the range of 0.5~0.9, accounting for about 90.8% of the total data. The ratio of $e < 0.5$ and $e > 0.9$ is smaller. Based on the statistical analysis of the above data, the coefficient of variation δ was 0.202 without deviating from any data and larger than the theoretical upper limit of 0.15. If the data of $e < 0.5$ and $e > 0.9$ are eliminated for their obvious deviation, the variation coefficient $\delta = 0.117 < 0.15$ (the theoretical upper limit value of variation coefficient), then the standard value Φ_k is 0.688, the maximum value 0.889, the minimum value 0.505, the average value $\Phi_m = 0.698$.

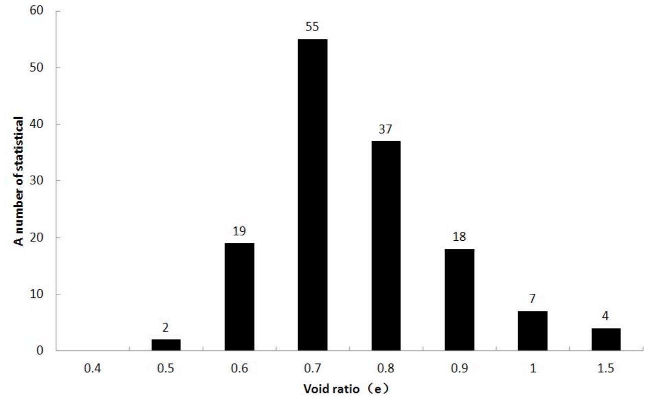

Fig. (3). Statistical histogram of natural void ratio distribution and number.

3.2.3. Calculating the Characteristic Value of Bearing Capacity

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

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 the actual project are counted according to the distribution interval, and the statistical results are shown in Table **5**.

3.3.2. Calculation and Analysis of Statistical Data

Using the statistical results, a data distribution histogram is performed (Fig. **4**).

From the above statistical results, cone tip resistance (q_c) data mainly concentrate in the range of 0.75-2.0,

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	$q_c < 0.5$	$0.5 \le q_c < 0.75$	$0.75 \le q_c < 1$	$1 \le q_c < 1.25$	$1.25 \le q_c < 1.5$	$1.5 \le q_c < 1.75$	$1.75 \le q_c \le 2$	$q_c > 2$
Number	43	47	207	223	190	174	153	58

Table 6. Bearing capacity comparison analysis results.

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

accounting for about 86.5% of total data. The ratio of q_c <0.75 and q_c> 2 is smaller. According to the statistical analysis of the above data, the coefficient of variation δ was 0.617 without deviating from any data and larger than the theoretical upper limit of 0.3. If the data of q_c <0.75 and q_c> 2 are eliminated for their obvious deviation, the variation coefficient δ=0.267 < 0.3 (the theoretical upper limit value of variation coefficient), then the standard value Φ_k is 1.367, the maximum value 2, the minimum value 0.76, the average value Φ_m = 1.386, the data number n = 918.

3.3.3. Calculating Characteristic Value of Bearing Capacity

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

4. DETERMINATION OF BEARING CAPACITY OF SILTY SOIL

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

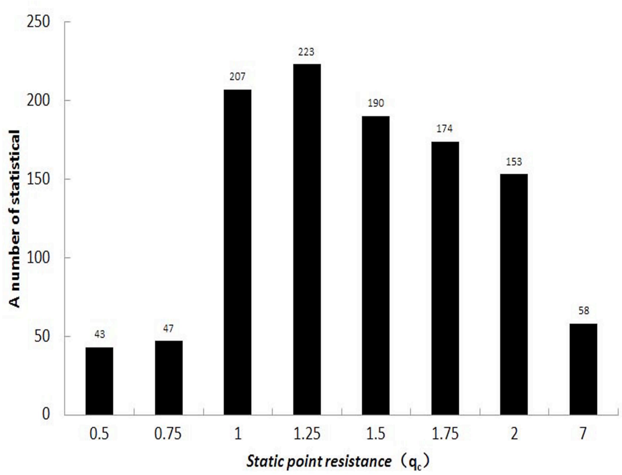

Fig. (4). Statistical histogram of cone tip resistance and number.

From the above table, the eigenvalues of bearing capacity of the silty soil calculated by standard penetration method and double bridge CPT method match better. Therefore, it is more appropriate to take the eigenvalue of silty soil bearing capacity of 130 kPa. The recommended value is closer to the current experience in the region, that is, 100 ~ 130kPa. However, the value obtained by soil test is greater than 50kPa.

CONCLUSION

In Binzhou area, standard penetration test and double bridge CPT match better to determinate the bearing capacity of the silty soil. However, the bearing capacity of the silty soil obtained by soil test is greater than 50kPa.

The eigenvalues of bearing capacity is suggested to be 130kPa that is closer to the empirical value in this area.

The standard penetration test and double bridge CPT should be paid more attention to the silty soil sediment in Binzhou area in the investigation work, which can make a more accurate conclusion.

CONFLICT OF INTEREST

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

ACKNOWLEDGEMENTS

This paper is aided by the National Natural Science Foundation (41172222, 41472216) and Science and Technology Development Plan Project of Jinan (201303082).

REFERENCES

[1] J. G. Wang, "Determination method of bearing capacity of silty soil in zhengzhou area", *Journal of Guilin University of Technology*, vol. 30, no. 3, pp. 374-377, 2010.
[2] Z. Y. Guo and C. P. Liu, "Determination of bearing of silty soil in Hu aibei, anhui ", *Geotechnical Engineering World*, vol. 7, no. 3, pp. 38-39, 2004.
[3] H. L. Wei, Y. Z. Yu and S. L. Sun, "Application of static sounding determination of silt, sand carrying capacity", *West Exploration Engineering*, vol. 9, no.4, pp. 13-14, 1997.
[4] GB50021-2001(2009 ed), Code for Investigation of Geotechnical Engineering, CN: Beijing, pp.131-134, 2010.
[5] Engineering Geology Handbook Edition Committee, Engineering Geology Handbook(4th ed),CN: Beijing, pp.332-336, 2002.
[6] X.L.Gu, "Foundation and Basic(3rd ed)," CN: Beijing, pp.92-93, 2003.
[7] DB42/242-2003, "Base Design Criterion Of Construction Foundation ," CN: Wuhan, pp. 164-166, 2003.
[8] DBJ15-31-2003, "Base Design Criterion Of Construction Foundation," CN: Guangzhou, pp. 30-34, 2003.
[9] GB 50007-2011, "Base Design Criterion Of Construction Foundation," CN: Beijing, pp. 14-16, 2011.

Received: January 15, 2015 Revised: March 28, 2015 Accepted: April 03, 2015