

Study on the ground mechanics index of deep soft foundation sections in the Dongting Lake region

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Abstract. Due to its special geographical location, the Dongting Lake Plain has formed a unique Dongting Lake phase deep soft ground layer. In order to investigate its stratigraphic mechanical index, a research was carried out using pile foundation static load test and pile body stress test based on a trans-Dongting Lake high speed project. The results of the study show that the ultimate bearing capacity of the test piles in this project is greater than the ultimate bearing capacity of the piles proposed by the design, and the reasons for this deviation according to the pile stress test are mainly due to the clay layer, silty powder clay layer and the side friction resistance of the fine gravel layer at the end of the pile are significantly greater than the recommended value of the ground investigation data, while the side friction resistance of the fine sand layer, powder fine sand layer and gravel sand layer is basically the same as the recommended value of the ground investigation data, This can be used as a reference for similar projects in the future.

Keywords: Dongting Lake, Deep soft foundation, Pile bearing capacity, Mechanical index.

1. Introduction

After tens of thousands of years of geological evolution, the unique Dongting Lake soft soil deposits have been formed in the region. The stratigraphic structure is generally characterized by soft-fluvial clay and silty powder clay of the Holocene; stiff plastic sandy silty clay; powdered fine sand, etc., and the underlying Pleistocene sand and gravel layer. The physical and mechanical indicators of the soft soils in the Dongting Lake area differ greatly from those of the marine and gulf phase soft soils. The natural water content, pore ratio and liquid-plastic limit of the soils are relatively low, and they are medium to high compressibility soils, with horizontal permeability coefficients significantly greater than vertical permeability coefficients, anisotropy ratios reaching more than 10 times, relatively dense structure and high mechanical strength.[1-2] .

At present, the Dongting Lake area bridge location area soil mechanical indicators are mainly based on in-situ testing and indoor test results and other comprehensive analysis, with reference to the "Highway Bridge Foundation and Foundation Design Code" (JTG D63) and other relevant codes and regulations of empirical data, which leads to the geotechnical bearing capacity, side friction resistance and other mechanical indicators are not accurate enough or too conservative, often making the design pile length is too long, not only is not conducive to pile foundation This is not only not conducive to the full play of the bearing capacity, but also low economic efficiency. Through the pile foundation static load test in the deep soft foundation area of Dongting Lake, we can obtain Indicators of realistic pile-earth mechanics parameters in the area provide a reference for the design of bridges in similar geological conditions.

2. Overview of the project

Nan Yi Expressway is the northern section of Nanxian to Changning Expressway, connecting Hangrui Expressway and Changchang Expressway, connecting Nanxian, Maocao Street, Yuanjiang and Yiyang. It adopts motorway standard, fully closed, full interchange, design speed is 100km/h, two-way four lanes, roadbed width is 26m, design load is highway - I grade. The route through the topography of the Dongting Lake Plain, stratigraphy is mainly the Quaternary Holocene (Q4) and the Quaternary Upper Pleistocene Baishuijiang Group (Q3b) strata, is a lacustrine sedimentary area, the

cover layer is huge thick, to alluvial genesis is the main distribution of the Quaternary silt, clay, fine sand, gravelly sand, round gravel, etc.. This section of soft foundation is widely distributed, mainly silt, sandy silty soil and clay, its physical and mechanical properties are poor, the foundation form is mainly based on bored friction pile.

3. Overview of test piles

In order to grasp the actual bearing capacity of the bored friction pile and the actual mechanical index of the pile soil in the area, to assess the safety of the pile foundation in the bridge area, and to obtain the design parameters of the soil layer on the side of the pile through on-site measurements so as to provide a basis for the optimal design of the pile foundation for bridges with similar geological conditions, five test piles were selected for the pile foundation self-balancing static load test in representative sections of the line to determine the bearing capacity of the pile. In addition, one test pile will be selected for the anchor pile method pile foundation static load test and pile soil stress test to determine the pile body bearing capacity, end resistance and pile perimeter soil side friction resistance. 6 test piles are bored piles, designed as friction piles, with pile length through the typical soft ground and fall in the good mechanical properties of the gravel layer.

4. Analysis of test results

4.1 Analysis of self-balancing static load test results

The design loading value and the selection of the balance point of the self-balancing pile foundation static load test are based on the distribution of the stratigraphic data and the suggested parameters provided by the ground investigation.

The vertical compressive ultimate load carrying capacity P of a single pile is derived from equation (1) and the pile top displacement S corresponding to the equivalent pile top load P is derived from equation (2) (3).

$$P = \frac{Q_u - W}{\gamma} + Q_l \tag{1}$$

$$S = S_l + \Delta S \tag{2}$$

$$\Delta S = \frac{[(Q_u - W) / \gamma + 2Q_l]L}{2E_p A_p} \tag{3}$$

Where: P : vertical compressive ultimate load carrying capacity of the test pile (kN); Q_u : load when the absolute value of displacement in the curve $Q_u - S_u$ is equal to S_u ; Q_l : load box downward load (kN), can be directly determined; S_l : load box downward displacement, can be directly determined (mm); W : self weight of the upper pile of the test pile load box (kN); γ : correction factor of the upper pile soil of the test pile, taken as 0.8. L : length of upper pile (m); E_p : pile modulus of elasticity (kPa); A_p : pile cross-sectional area (m^2).

Table 1 is the self-balancing static load test results summary table, from the table can be seen when loaded to the design of the maximum load value after the pile top equivalent conversion displacement are small (maximum 38.61mm) and has reached stability standards, at this time the pile foundation has not reached the ultimate bearing capacity, there is still a large surplus. Therefore, it can be judged that there is still room for optimisation of the pile and soil mechanical parameters in this area.

Table.1. Summary of results of static load tests on self-balancing pile foundations

Test Pile Number	Test pile location	Pile diameter (m)	Pile length (m)	Depth of equilibrium point (m)	Design pile ultimate load	Measured pile ultimate bearing	Measured maximum equivalent pile top
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					capacity (kN)	capacity (kN)	displacement (mm)
Sz1	K69+180 Man-made canal bridge, platform 0	1.2	24	21.5	8200	≥10473	9.62
Sz2	K2+187.5 Nanzhou Special Bridge Pier 42	1.2	56	51	11,400	≥11699	28.84
Sz3	K13+610.5 at Nanmao Canal Special Bridge Pier 150	1.2	55	49	11,400	≥11769	38.61
Sz4	K35+880.5 Wuqi Canal Special Bridge Pier 20	1.2	42	36.5	11600	≥11761	12.99
Sz5	K63+425.31 Pier 18 of Baisha Yuanshui Special Bridge	1.2	44	37	10800	≥13270	14.85

4.2 Analysis of stress test results

(1) Overview of pile stress tests

In order to obtain comprehensive mechanical indicators of the main strata in the Dongting Lake area, the test site of Sz6 pile foundation stress test was selected in the most complex geological conditions of the whole section, the test pile location is located at K24+644 Satellite Village separated three-dimensional intersection No. 0 platform, the loading method uses the anchor pile method, using the existing engineering pile and bearing platform as the reaction system, the loading schematic diagram is shown in Figure 1. the test pile diameter is 1.2m, pile length is 40m, according to the friction pile Design. According to the ground investigation data, the design ultimate bearing capacity is 17000kN. according to the self-balancing test results, in order to obtain the maximum ultimate bearing capacity of the test pile, the actual maximum loading value is 26000kN, divided into 10 levels of loading. Before the pile foundation was cast, the reinforcement gauge was pre-layed on the reinforcement cage for pile stress test, 8 sections were laid out, 4 reinforcement gauges for each section, the sections were buried as close as possible to the soil parting interface, for thicker soil layers were encrypted, the specific laying position is shown in Table 2.

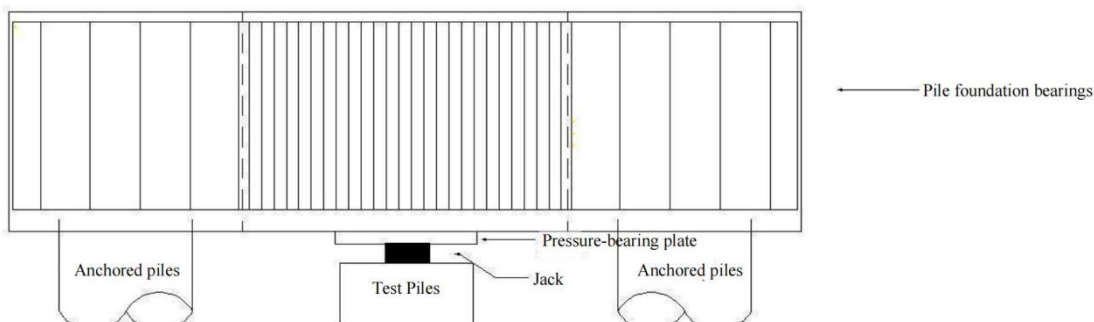


Figure 1 .Schematic diagram of the Sz6 anchor pile method of loading
Table 2. Location of Sz6 pile stress sections and corresponding geological conditions

Soil layer number	Name of soil layer	Thickness of soil layer (m)	Section location
1	Powdered clay	1.8	
2	Silty chalky clay	6.6	1 section (calibrated layer)
3	Clay	9.4	1 cross-section
4	Sandy silt loam	0.9	
5	Fine sand	6.1	1 cross-section
6	Powdered fine sand	5.7	1 cross-section
7	Sandy silt loam	3.2	1 cross-section
8	Gravelly sand	3.0	1 cross-section
9	fine gravel	≥14	2 cross-sections

(2) Bearing capacity test results

Figure 2 shows the static load test results of Sz6, the actual maximum loading value is 20,800kN, under the action of the maximum test load, the total settlement of the pile is 40.85mm; and the settlement of this level is 36.37mm, which is five times greater than the settlement of the previous level load of 3.23mm. According to the specification, the vertical ultimate bearing capacity of the test pile was taken as 18200kN for the previous level of load, which was greater than the design ultimate bearing capacity of 17000kN, which was consistent with the results of the self-balancing static load test.

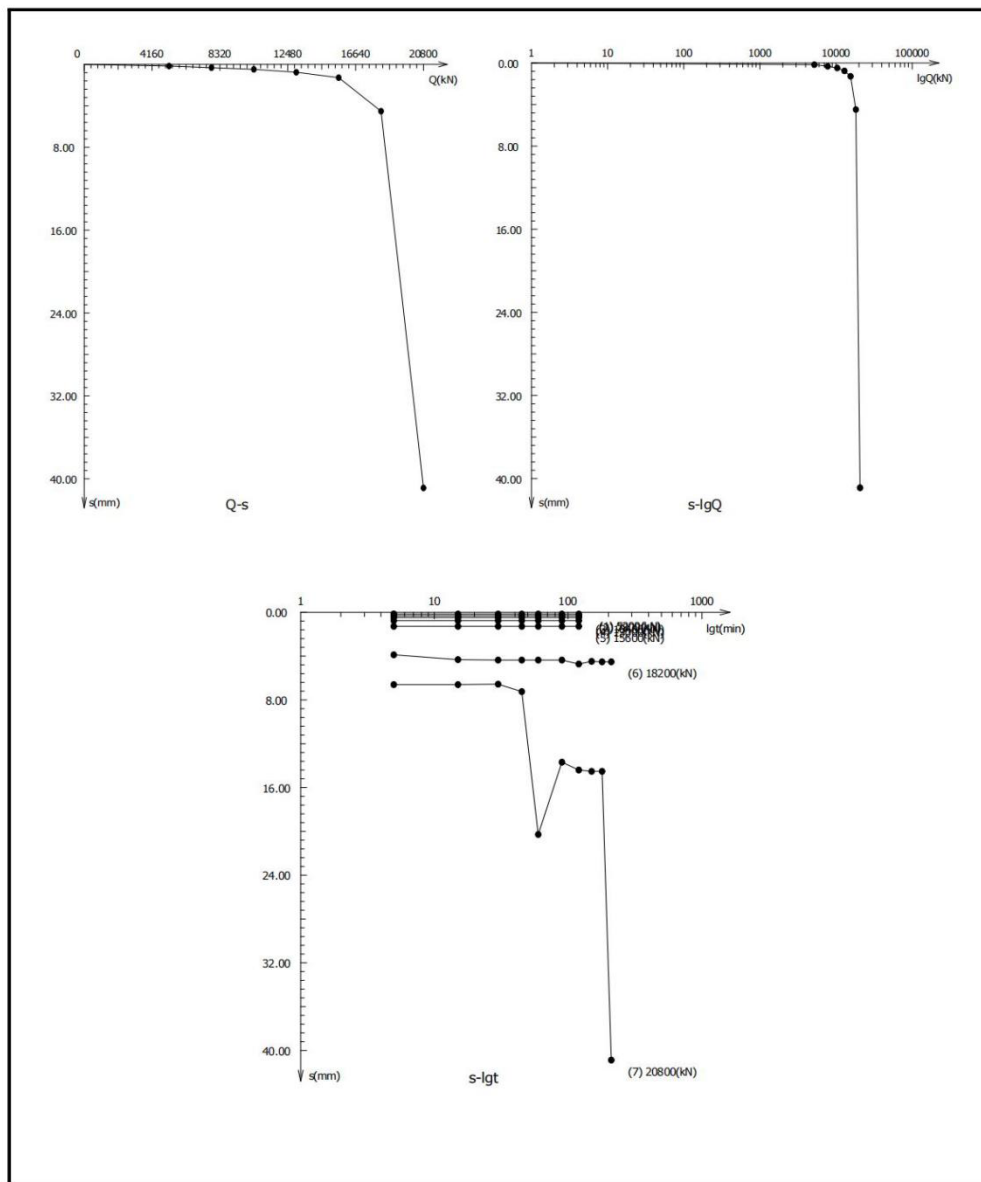


Figure 2. Test pile load to displacement curve and test pile displacement to time curve

(3) Pile stress test results

The pile shaft force is obtained by polynomial curve fitting between the section shaft force obtained from the steel gauge shaft force calculation and the actual shaft force. The average pile lateral friction resistance q_{si} for each sub-layer of soil can be calculated according to equation (4), assuming the same lateral friction resistance for each sub-layer in the calculation process.

$$q_{si} = \frac{Q_i - Q_{i+1}}{d \pi l_i} \tag{4}$$

Where: Q_i - i -th section axial force (kN); l_i - i -th stratified pile side length (m).

The pile axial force results for Sz6 are shown in Figure 3 and the lateral friction resistance results for the soil layers are shown in Figure 4 and Table 3. It can be seen from Figure 3 and Figure 4 that the lower pile axial force and lateral friction resistance gradually increase with increasing pile top load until the ultimate load is reached. Table 3 shows that the measured lateral friction resistance of fine sand, fine sand and gravelly sand is basically the same as that suggested by the ground investigation data, but the lateral friction resistance of clay, silty powdered clay and fine gravelly layer at the end of the pile is significantly higher than that suggested by the ground investigation data, which may be due to the fact that the soft soil layer and fine gravelly layer are easily disturbed by the test and sampling factors, resulting in inaccurate values.

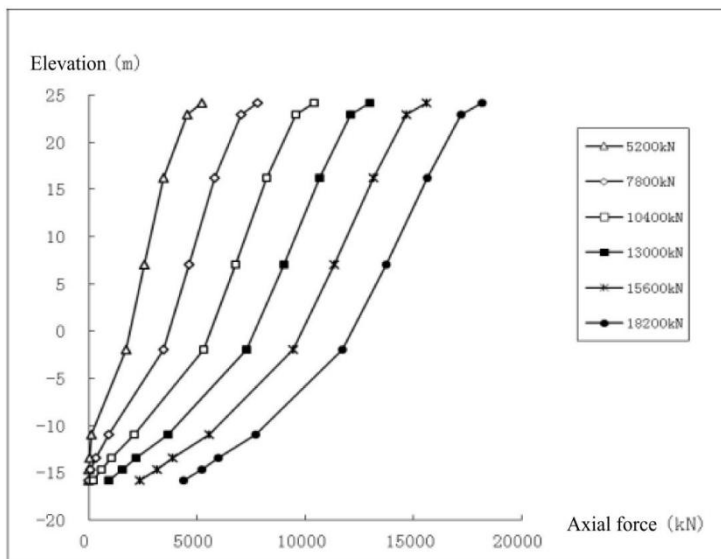


Figure 3 Distribution of pile shaft force with depth

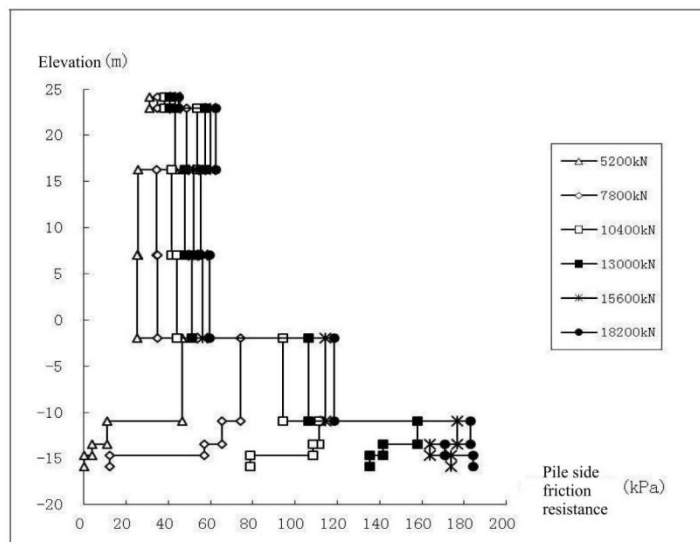


Figure 4 Distribution of average frictional resistance at different depths of the pile side for different levels of loading

Table 3 Distribution of average frictional resistance and end resistance at different depths of the pile side

Part	Test limit friction (kPa)	Design limit lateral friction resistance (kPa)	Test limit end resistance (kPa)	Corresponding soil name
Soil layer 1	44.7	/	/	Silty chalky clay
Soil layer 2	62.3	55	/	Clay
Soil layer 3	55.2	55	/	Fine sand
Soil layer 4	59.7	55	/	Powdered fine sand
Soil layer 5	55.2	20	/	Sandy silt loam
Soil layer 6	118.6	110	/	Gravelly sand

Part	Test limit friction (kPa)	Design limit lateral friction resistance (kPa)	Test limit end resistance (kPa)	Corresponding soil name
Soil layer 7	171.0	150	/	fine gravel
Soil layer 8	184.2	150	3859	fine gravel

5. Conclusion

Dongting Lake, as the second largest lake in China with a basin plain area of about 50,000 square kilometres, is becoming one of the most dynamic areas of development in the middle reaches of the Yangtze River, and the study of its stratigraphic mechanical indicators is of great significance. In this paper, relying on the Hunan Nangyi Expressway, the ground mechanics indexes of the route area were studied using pile foundation static load tests and pile stress tests, which showed that.

(1) 5 representative strata along the route were selected for pile foundation self-balancing static load test, loaded according to the design limit value, the final pile top displacement are small, the pile bearing capacity did not give full play to, still has a certain potential.

(2) The anchor pile method pile foundation static load test and pile stress test were carried out in the more complex geological strata of the route. The measured ultimate pile foundation bearing capacity was 18,200kN, which was greater than the design ultimate bearing capacity of 17,000kN, and also verified the results of the self-balancing static load test.

(3) The lateral friction resistance of the clay, silty pulverized clay and fine gravel layer at the end of the pile are significantly higher than those suggested by the ground investigation data, indicating that the mechanical index of the soft ground in the Dongting Lake area is better than that of the general soft ground, which can provide reference for subsequent similar projects and make the design more reasonable.

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