Several Conclusions from Standard Test Method for Piles Under Static Axial Compressive Load

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Keywords: Steel pile, Test on steel pile under static axial compressive load, Analyse, Advise.

Abstract. Based on test constructed on steel pile on a container terminal, the writer introduces the test method for steel pile under static axial compressive load, and analysis the data received form the test. In addition, the writer also gives some advices on piles test under static axial compressive load.

Introduction

Standard Test Method for Piles under Static Axial Compressive Load is also called the static load test of pile foundation, which is a mature technology test methods about bearing capacity of pile foundation. In determining the bearing capacity of single pile, it is currently the most accurate and reliable testing method that Standard Test Method for Piles under Static Axial Compressive Load which compared with the LOAD cases of self-balancing method (O-Cell method), high strain dynamic TEST (PDA) and compared that at present in our country Taiwan area, Japan and some southeast Asian countries, the application of a wide range of static and dynamic TEST method (STATNAMIC LOAD TEST, a kind of speed between static LOAD method and the method of pile foundation bearing capacity between TEST method). To determine whether inspection method about a certain bearing capacity of pile foundation is mature, it’s based on the comparison error of the results of the load test and maintenance load. This test’s the specific practice is the following that the pace is stepping loading. Before the pile sinking did not reach the standard is relatively stable, maintain the level of load constant; Then when it reaches stable standard, continue to add to the next level load; Finally When the specified termination test condition is reached, the load is terminated; Then we should make the load shedding reach to zero. Test cycle is commonly 2 ~ 5 days.

The study is based on overseas container terminals to carry out a steel pipe pile composite slab pile structure of steel pipe pile load test. The paper introduced the this experiment method, analyzed and discussed the test data and proposed suggestions combining with the test results.

Project Profile

It is used φ2.3 m steel pipe pile and AZ26 shape steel sheet pile composite structures as dock front wall that outside of a steel pipe pile composite slab pile container terminal. The pile top’s designed elevation is + 1.1 m, the bottom elevation is - 38 m, the length is 39.1 m and the wall thickness is 24 mm using the bridle rod and anchor wall to anchor them. Through AZ26 type steel sheet pile, lock is used to connect with the steel pipe piles. It is used φ1.0 m steel pipe pile that guideway pile foundation of rail bearer. The pile top’s designed elevation is + 2.3 m, the bottom elevation is - 36 m, the length is 38.3 m and the wall thickness is 18 mm. A typical layout as shown in fig.1 wharf pile foundation.
According to the project technical specification’s requirements, dock front wall from 2.3 m steel pipe pile and orbit after 1.0 m are respective to arrange a set of steel tubular piles to Standard Test. The steel pipe pile’s selection is in A50Ω2.3m; The Ω1.0m steel pipe pile’s selection is in B8 pile. And designing of vertical load is respective for 5567 kn and 5237 kn. What’s more, the experiment asks each group to perform twice the designing load of load test and then in the same root pile conduct 2.5 times of the designing load of fast load test. B8 pile’s basic information is as follows.

Table 1. B8 pile basic information.

<table>
<thead>
<tr>
<th>Stake mark</th>
<th>B8</th>
</tr>
</thead>
<tbody>
<tr>
<td>The pile type and specification (mm)</td>
<td>Ω1000δ18, length is 40.0m</td>
</tr>
<tr>
<td>construction equipment</td>
<td>Sink of the hydraulic vibration hammer vibration</td>
</tr>
<tr>
<td>Supplementary pile measures</td>
<td>Rotary digging inside piles reaches to -21 m</td>
</tr>
<tr>
<td>The actual pile top elevation (m)</td>
<td>+3.91</td>
</tr>
<tr>
<td>The actual bottom of pile elevation (m)</td>
<td>-36.09</td>
</tr>
<tr>
<td>Design of pile bottom elevation (m)</td>
<td>-36</td>
</tr>
<tr>
<td>Pile in clay surface elevation (m)</td>
<td>-4.19</td>
</tr>
<tr>
<td>Pile construction date</td>
<td>14 years on September 29</td>
</tr>
<tr>
<td>Experimental date</td>
<td>15 years on June 23, 24</td>
</tr>
</tbody>
</table>

Ps: The actual purchasing pile’s length is 40.0 m

The engineering area is dominated by sand including with a small amount of clay and alternating top-down distribution. The domain ranging from -17m to -23m has a coral and coral reef limestone; The domain -28m to -32m or ranging from -22m to -35m has a discontinuous lens of cementation sand layer.

The Experiment Process and Technical Requirements

Experiment Method

The test used four anchor pile and anti forces of beam method to carry on the maintenance load and the quick loading respectively. To maintain load, we put to use as per 25% of the loading of the pile foundation in the designing load level and load in all eight times. Rapid loading method is per loading of 2.5 times the pile foundation design load level of 5%, and load 20 level. According to the total test load of 25%, the unloading is 4 level.
Experiment Equipment

The main equipment are shown in Table 2.

Table 2. The main instrument table.

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Instrument and equipment</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jack</td>
<td>5000kN</td>
<td>Three</td>
</tr>
<tr>
<td>2</td>
<td>Precision oil pressure gauge</td>
<td>0.4 level</td>
<td>One</td>
</tr>
<tr>
<td>3</td>
<td>high pressure oil pump</td>
<td>Customization</td>
<td>A set</td>
</tr>
<tr>
<td>4</td>
<td>Vibrating wire reading instrument</td>
<td>BGK-4000</td>
<td>Forty-six</td>
</tr>
<tr>
<td>5</td>
<td>Vibrating wire reading instrument</td>
<td>BGK-408</td>
<td>A set</td>
</tr>
<tr>
<td>6</td>
<td>Electron displacement meter</td>
<td>50 $\mu$m</td>
<td>eight</td>
</tr>
<tr>
<td>7</td>
<td>Electron displacement meter</td>
<td>100 $\mu$m</td>
<td>five</td>
</tr>
<tr>
<td>8</td>
<td>static strainometer</td>
<td>DH-3815</td>
<td>A set</td>
</tr>
<tr>
<td>9</td>
<td>Level</td>
<td>DSZ2</td>
<td>A set</td>
</tr>
</tbody>
</table>

Experiment Arrangement

Test system is made up of loading system, the reaction system and measurement system (Fig. 2).

Loading device: using the three hoisting jacks bearing 500 tons force in parallel to the hydraulic tubing and pressure gauge. Being driven by a hydraulic pump and maintain its operation. The above’s purpose is used to ensure the pressure synchronous. Putting three jacks line symmetry and making the resultant force coincide with the test pile of longitudinal axis.

Reaction system: pressure from jack via a main beam and two beams transmits four anchor piles. The main beam’s and secondary beam’s stiffness and strength should be largely enough to avoid excessive deflection under the load. the pulling force of anchor pile should be through the review, to provide sufficient reaction.

![Figure 2. Schematic diagram of experimental apparatus.](image)

Measurement system: Reference pegs supported datum line beam; The reference peg with the test interval is not less than 2.5 m as far as possible away from the anchor pile. Benchmark beam must be stable enough to support the measurement instruments, so as to avoid excessive volatility reading. Measurement adopted by the electron displacement meter range 50 mm, and the accuracy is not less than 0.25 mm.

Stress Testing

In pile body, we symmetrically arrange two measuring lines. According to the test pile of geology, select 23 strain test section, which is in total of 46 steel string strain gauge. Through the analysis of the pile body of measured strain, we can calculate axial stress of pile. Then we could calculate the interaction of pile and surrounding soil—the pile side resistance. Strain gauge and its wire will be protected with channel steel. Because channel steel resulting in welding of high temperature is easy to burn out sensor wire. So this experiment uses wet yellow laying on the wire to protect them. This
method is simple and effective. And embedding of 46 was detected in 45 of strain gauge signal, so the survival rate reaches 97.8%.

Displacement Observation

**The Pile Top Displacement Observation.** Under the top of the pile ranging from 0.2 m to 1.0 m, we symmetrically install four electron displacement meters which measure the sink of pile top. In the four anchor piles, we respectively install a electronic displacement meter measurement quantity and electronic displacement meter is installed on the beam. At the same time we used level instrument as the measurement of auxiliary system and check the data about electronic displacement meter each other.

**The Pile Body Displacement Measurement.** According to geological data, in the pile body we select five typical test section. In the point which locates at steel pipe pile, we welded on the steel bar near the pipe wall. Making steel extension to cap as a measuring rod, we used electronic displacement meter to measure per level measurement under the load of sedimentation. Measuring rod should weld channel steel to protect, and along the different pile height, we welded steel plates being separated by five small rod to ensure the verticality of measuring rod.

Pile settlement observation points were set up with the pile top which’s the distance is 2.5 m, 12.5 m, 25.6 m, 33.6 m, 38.7 m.

Test Loading and Unloading

According to the 25% stage load of single pile design load, we carry through the stepping loading. The stability criteria for each level is the following. The settlement rate is not more than 0.25mm per hour [1], but the rate is maintained at no more than two hours.

After loading to 200% of the design load, under the condition of no damage about the test of pile foundation and the settlement of pile top in one hour is less than 0.25 mm, the test should class unloading that is the test load after maintaining loading last 12 hours; Otherwise the total load last for 24 hours on pile foundation. After the hold time requirements, it unloads gradually, and each time the test reduces 25% of the total test load, and the time interval is an hour.

Termination of Loading Condition

With reference to the regulation: Specification for Testing of Pile Under Static Load in Harbour Engineering (JTJ 255-2002) [2], when one meets the following conditions we can stop loading.

The total settlement of pile head is more than 40 mm (the steel pipe pile appropriately large), and under a certain classification load, the settlement of piles is 5 times higher than that of the previous one.

Under a certain classification load, it is not stable in 24 hours.

The Q - S curve no obvious steep fall in the period of S curve, pile top total settlement reached 60-80 – mm.

Load has reached the bearing capacity of test pile.

In the process of loading, it found test pile bolck’s displacement off the axis is too large, which endangers the test safety.

The amount of test load meets the design requirements.

Fast Loading Test

After maintaining the test load classification (according to 25% of the total test load we used level 4 unloading) and when the unloading time reaches 30 minutes, we used the method of rapid load and load to 250% of designing load. Then we made per level loading reach 2.5 times the test load of 5%.Finally we used 25% of the total test load to class unloading.
The Experimental Results and Data Analysis

Pile Top Settlement Under All Levels of Load

The settlement of the pile top and the chart of the top of the pile under various loads are shown in Fig.3, Fig.4.

![Standard loader Q-S curve](image)
![S-lgt curve](image)

According to measurement results of the pile top settlement and Q-S curve, we knew when the standard loading program reaches to 200% of pile design load (10474kN), the biggest pile top settlement is 60.71mm, but in 12 hours, the last 3 hours the pile settlement was less than 0.25mm per hour, reaching to a stable standard—ASTM-1143 standard. And the design requirements of technology projects is that the settlement of pile top is not greater than 100mm. So we judged the pile is stable in the 200% pile design load. After the unload is up to zero, the residual settlement is 36.60mm. The Q-S curve has no obvious drop off, the S-lgt curve is a slow deformation, and the curve did not appear significantly steeper slope or tail significantly downward bending. Thus we thought the test had not been damaged when the standard loading program reaches to 200% of designing test load, and it shown the ultimate bearing capacity of pile is greater than 10474kN.

But at the same time it should be noted that under the action of 10474kN, the walk lines about the settlement of Q-S curve and S-lgt curve are applied on a level of load changes obviously, and the bearing capacity of pile foundation has been close to the limit damage condition.

In the fast loading test, when the maximum settlement of the pile top was 86.09mm when the load was 95% (12438kN). In the process of the applied test load —13093kN, once the site start the pump pressure, the pile will continue to settle, so it could not be stable, and the test ended.

With reference to the results of maintenance load test and rapid loading test, we judged the ultimate bearing capacity is 12438kN (The damage of rapid load test occurred at the next higher level in the test load).

Axial Force, Pile Tip Resistance and Pile Side Friction Resistance

In the test, firstly, the strain values of each point on the pile are measured, then the axial force of the section is calculated according to the measured values. And we could calculate the limit of pile’s lateral friction in each soil layer. The distribution of axial force along the pile is shown in Fig. 5.
Conclusions and Suggestions

According to the results of maintenance load test and fast load test, the ultimate bearing capacity of B8 pile is 12438kN, which is 2.375 times of the pile foundation designing load that is 5237KN, and the safety factor of the pile is 2 times.

The regulation—"JTJ 255-2002 Specification for Testing of Pile Under Static Load in Harbour Engineering" rules: the test pile can be damaged, instead the engineering piles is only used to verify the design, so it can not be damaged. However, we used hydraulic vibration piling hammer to be pile-sinking, and itself is the use of high frequency liquefaction to destroy the soil pile, so the settlement of pile obviously subsided in process of construction. The specification is whether the test can relax a similar pile method to a hydraulic vibratory hammer, which allows the construction of this type of construction method to do damage. The pile is firstly sunk to a certain distance (such as 0.5m), and after the completion of the test, the hydraulic vibratory hammer is used to design the bottom elevation, instead the pile length which was not sunk to elevation can be calculated by the measured side friction. (3) With the ultimate side friction measured by B8 pile, we checked on the steel pipe pile that its diameter is φ23mm on the wharf shoulder. it can be increased by 2689KN that the measured results was compared to A50 pile in respect of the ultimate bearing capacity (The pile rapidly loading to 2.5 times was not destroyed, and the maximum settlement is 19.73mm, as the pile is no damaged). According to this result, we can optimize the design of pile length 5m. This project’s A type of pile is a total of 296, only this one, and you can save 2000 tons of steel piles, saving the purchase cost of $2 million 600 thousand. At the same time, because the engineering geology don’t have discontinuous cement sand, optimization of pile length can not only save procurement costs, but reducing the difficulty of construction (Rotary drilling process can be saved) and saving the time is also very useful.

References
