Hydraulic cell and Bi-direction pile load test related technology

1. Hydraulic cell

1. Types and specifications of hydraulic cells

1) Classification of piston motion types

The hydraulic cells used in bi-directional pile load testing are classified based on the motion type of the piston as 'Single-Acting' and 'Double-Acting.'

2) Classification according to hose specifications

High-pressure hoses are classified into three categories based on their specifications: 700kg/cm^2, 1000kg/cm^2, and 1500kg/cm^2. As the operating pressure decreases, the size of the hydraulic cell increases.

3) Load range

The hydraulic cell is selected and used from six different load ranges: 400, 600, 800, 1000, 1200, and 1500 ton·f, based on the piston's operating mode and hose specifications.

2. Calculation of loading on hydraulic cell

1) The load on the hydraulic cell is calculated by multiplying the working pressure by the piston's cross-sectional area.

Load (ton·f) = Piston Cross-sectional Area (cm^2) x Working Pressure (kg/cm^2)

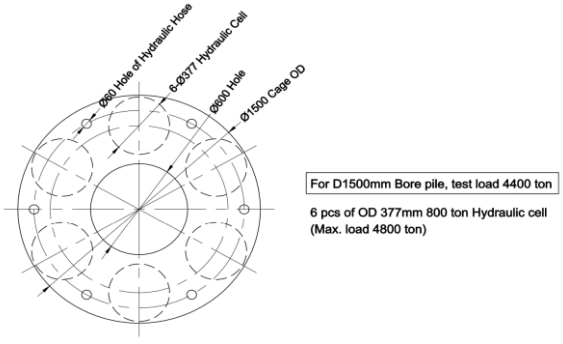
For example, in the case of the 800ton hydraulic cell mentioned above, the piston's cross-sectional area is 538cm^2.
If a working pressure of 1000kg/cm^2 is applied, the load on the hydraulic cell would be 538ton·f. Similarly, if a working pressure of 1500kg/cm^2 is applied, the load would be 807ton·f. The loading on the hydraulic cell is determined by the applied pressure.

2) The loading on the pile is calculated by summing up the individual loads of the hydraulic cells installed in the cage.

Loading on the pile (Σton·fn) = Load on cell 1 (ton·f1) + Load on cell 2 (ton·f2) + ... + Load on cell n (ton·fn)

3. Cage design

To secure the hydraulic cells to the pile and apply the loading, it is necessary to use a cage. The cage consists of an upper plate, lower plate, and is also referred to as the 'Bearing plate.'
One or multiple hydraulic cells are fixed simultaneously to the upper and lower plates during installation, and the loading of each hydraulic cell is combined to exert a total load on the pile. When designing the cage, it is necessary to create one or two larger holes to allow the passage of tremie pipes for grouting. Additionally, holes for extracting hydraulic hoses are also required and must be carefully reviewed.
When arranging hydraulic cells in the cage, one cell should be placed in the center, and multiple cells should be evenly distributed to ensure that the load is evenly distributed across the entire pile. The following is an example of a configuration where six 800ton hydraulic cells are arranged on a pile with a diameter of 1500mm and a loading of 4400tons.



2. Bi-direction pile load test (Cited from Industrial Standard KS F 7003)

1. Bi-directional load testing apparatus

1) The pressurizing equipment used in the bi-directional pile load testing apparatus must undergo calibration and verification. In order to enhance the accuracy of the load and the reliability of the test, the pressurizing equipment, pressure sensor, hoses, and pressure pump assembled as they would be used in the actual field should be calibrated and verified up to at least 70% of their nominal capacity.

2) Pressurizing equipment of bi-directional pile load testing apparatus should be able to meet the planned maximum load and have sufficient stroke to induce the anticipated displacements during the test.

3) In the case of using multiple pressurizing equipment, they should have the same specifications and be capable of interlocking control.

4) Valve devices for pressurized hoses should be undamaged and have sufficient pressure capacity.

5) The pump should have sufficient discharge capacity to correspond to the load capacity and the set load rate of the bi-directional pile load testing apparatus.

6) The pressurizing device of the bi-directional pile load testing should be installed according to the testing purpose, but when the purpose is to verify the design bearing capacity of the pile, it should be installed at a position where the lower and upper support forces are in equilibrium.

2. Standard loading method

1) The planned maximum load is divided into 8 or more stages for loading.

2) Load maintenance, load release, and load reduction follow the slow load testing method and rapid load testing method specified in KS F 2445. The criterion is based on the displacement of the upper and lower plates of the pressurizing device being less than 0.25 mm per hour.

3. Cyclic loading method

1) The planned maximum load is divided into 8 or more stages for loading.

2) Load maintenance, load release, and load reduction follow the repeated load testing method specified in KS F 2445. The criterion is based on the displacement of the upper and lower plates of the pressurizing device per hour.

4. Measurement category & timing for load test

1) Measurement category

- Time
- Load
- Downward/Upward displacement of the pile head and bi-directional pressurizing device
- Displacement of the shaft and intermediate sections
- Strain of the pile body (strain or stress measured by sensors installed at different depths for load measurement)
- Displacement of the surrounding soil near the pile

2) Measurement timing

All data should be measured automatically, and the measurement items in the automated measurement system should be continuously measured in real-time from the beginning to the end of the test as the standard.

KS F 2445:2022

Compression load testing methods and comparison				
Test method	**Load stage**	**Load maintenance**	**Load termination**	**Load reduction**
Slow Load Testing Method	8 stages (25%, 50%, 75%, 100%, 125%, 150%, 175%, 200% of design load)	After a minimum of 30 minutes, the pile head settlement rate is maintained until it reaches below 0.25mm per hour (up to a maximum of 2 hours)	If the settlement rate is below 0.25mm per hour at 200% of the design load, it is maintained for 12 hours. If the settlement rate is higher than that, it is maintained for 24 hours	Load testing is performed with increments of 25% of the test load, with a one-hour interval between each stage
Excess Load Consolidation in Slow Load Method	In the slow load testing method, the load is increased in increments of 50% of the design load until reaching the excess load, and then in increments of 10% of the design load until reaching the maximum test load	Until reaching the maximum test load, the slow load testing method is followed. After that, the load is increased in 20-minute intervals until reaching the maximum test load	Load testing is conducted until reaching the maximum applied load or until failure (settlement of 15% of the pile diameter). If failure does not occur, the load is maintained for 2 hours	Load testing is performed with increments of 25% of the test load, with a 20-minute interval between each stage
Repeated Load Testing Method	Same as the slow load testing method	At the 50%, 100%, and 150% load stages, the load is maintained for 1 hour, while for the remaining load stages, the load is maintained for 20 minutes until full consolidation is achieved. After that, the load is increased in 50% increments, with each stage being maintained for 20 minutes during load testing	Same as the slow load testing method	Same as the slow load testing method
Rapid Load Testing Method	The load for each stage is 10% to 15% of the design load	Each stage is maintained for 2.5 to 15 minutes (usually 5 minutes), and settlement readings are recorded for 2 to 4 cycles	Load testing is conducted until reaching the ultimate load or the allowable limit, and then the load is maintained for 2.5 to 15 minutes (typically 5 minutes)	Load testing is conducted by dividing it into approximately 4 stages, with each stage being maintained for 5 minutes
Fixed Time Interval Testing Method	Load 20% of the design load per stage of 8	Each load stage is maintained for 1 hour	The load is maintained for 1 hour at 200% of the design load	Load testing is conducted with increments of 20% of the design load, and each stage is maintained for 1 hour
Fixed Settlement Rate Testing Method	After each stage, a fixed settlement rate (0.25mm/min to 2.5mm/min) is achieved before proceeding to the next stage of load testing	Cohesive soil: 0.25~1.25mm/min Granular soil: 0.75~1.25mm/min	Load testing is conducted until reaching the final test load or a total settlement of 50mm to 75mm, whichever comes first. The settlement limit is set at 15% of B (the diameter or diagonal length of the pile)	The total load is applied and maintained for 1 hour after reaching the desired settlement
Fixed Settlement Amount Testing Method	The load for each stage is determined to be approximately 1% of the pile diameter in settlement amount	When the settlement or rate of change in applied load per unit time is less than 1% of the total applied load per unit time	Load testing is conducted until reaching a total settlement of 10% of B (the diameter or diagonal length of the pile), or until the test load is reached	Load testing is conducted by dividing it into approximately 4 stages, and each stage is performed after the rebound ratio of each stage is within 0.3% of B (the diameter or diagonal length of the pile)

5. Test report

1) General information

a) Test objective

b) Test site and location

c) Test start, suspension, and resumption date and time

d) Test procedure

e) Weather conditions

f) Tester, analyst, and reporter

g) Pile location and number

h) Pile specifications and construction records

i) Installation location of load application devices

j) Relationship between pile and boring points

k) Ground elevation during boring and reference elevation during pile testing

l) Installation locations of measurement instruments (test locations, displacement gauges on load application device top and bottom, strain gauges on planes, depths, directions)

m) Calibration certificates for load application devices, sensors, and measurement instruments

2) Ground conditions

a) Location map

b) Information about burial sites (timing) and hilly areas, ground settlement information

c) Overview of ground, ground profile (elevation, groundwater level, survey timing specified), ground characteristics a) ground conditions

3) Test results

a) Time-load-displacement measurement results

b) Load-time curve

c) Plate displacement-time curve

d) Load-plate displacement curve

e) Load-plate elastic recovery curve

f) Load-plate residual displacement curve

g) Plate displacement-time curve

h) Load-plate displacement curve

i) Load-pile head displacement curve

j) Load-settlement curve when measuring settlement with load application device bottom and pile head disconnected

k) Load-midpoint displacement curve when measuring midpoint displacement

l) Load-surface displacement curve and distribution of surface displacement when measuring surface displacement

m) Load-time-plate

*** For detailed information about bi-directional pile load test (industrial standard KS F 7003), please refer to the national standards certification website.**