



Osterberg method of testing high capacity bored- piles

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ABSTRACT

It is obvious that for high-rise building construction there should be added additional requirements not only for designing, but also for organization and technology for foundations and underground parts of the building. Only qualitative calculations and entire engineering of geotechnical solutions will let to make really safe construction.

As a result of carried out analysis of literature, according to our view, due to appearance of new technologies and types of piles and also new requirements for increase of bearing capacity especially in high-rise building construction, aroused a necessity in application of new pile test methods which will allow setup of high capacity piles. Conducting of tests using hydraulic jacks and division of piles into segments is appropriate for high capacity piles when using standard test methods by vertical load is impossible technically or there is need to use huge anchor constructions, so using such methods is inappropriate economically and technically.

The Osterberg cell is very simple mechanically, and made of a metal piston and cylinder that create an expandable chamber holding pressurized oil or water. The pressurized oil acts on the piston, and taking into account that the piston is usually not less 800 mm in diameter, the Osterberg cell can apply relatively large loads for low hydraulic pressures. Loads of more than 2700 t. can be reached with the largest cells.

Characteristics of piles after tests with load cells are close to piles, which were not exposed testing, because residual stress in pile is less than the ones, which are left after applying full vertical load in standard tests.

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1. Introduction

The level of liability of design solution choice of zero cycle for high-rise buildings is higher than for typical constructions. Corrections of geotechnical mistakes are more complicated and expensive, sometimes even impossible.

It is obvious that for high-rise building construction there should be added additional requirements not only for designing, but also for organization and technology for foundations and underground parts of the building. Only qualitative calculations and entire engineering of geotechnical solutions will let to make really safe construction [1].

Whole complex of engineering survey operations, design and construction of every building need unique integral calculation and construction support. High-rise building are designed as tower construction with weight of 100 000 t. Input of wind load on foundations of high-rise buildings is considerably higher than for regular multistory buildings. Specific pressure on base under foundation can reach 500- 800 kPa. Architectural features of the constructions can lead to significant eccentricity on foundation base. It makes foundation design extremely complicated and critical process [2 - 5].

One of the fundamental and most complex problem while designing pile foundations is determination of pile bearing capacity and which consists of material strength and soil hardness, which receive pile load. Comparing with calculating of material pile resistance the calculation of bearing capacity of soils is much harder. Mistakes in these calculations are common reasons of declinations in work of real construction while designing pile foundations [6 - 9].

While designing pile foundations quality of piles should be emphasized. In project special testing piles are usually picked out in which special tubes are put in order to control quality of piles. If there is a horizontal load then deviation survey tubes is used. Quality control of concrete is conducted using radioisotope and ultrasound methods or by boring a core from the pile. Considering that for high-rise buildings deep and more than 2-meter diameter piles are used, so in project should be provided one of the nonstandard methods like Osterberg method [1, 10].

2. Literature review

Unfortunately, all methods of static determination of pile bearing capacity is brought to standard testing with vertical load according to GOST 5686-69 "Soils. Field test methods by piles" or devoted too little attention to modern methods of pile testing which foreign companies conducted in literature.

3. Problem definition

As a result of carried out analysis of literature, according to our view, due to appearance of new technologies and types of piles and also new requirements for increase of bearing capacity especially in high-rise building construction, aroused a necessity in application of new pile test methods which will allow setup of high capacity piles. Conducting of tests using hydraulic jacks and division of piles into segments is appropriate for high capacity piles when using standard test methods by vertical load is impossible technically or there is need to use huge anchor constructions, so using such methods is inappropriate economically and technically [1, 2].

A fundamentally new method of testing of bored piles using Osterberg method and its comparison with standard pile testing by vertical load is considered in this article.

4. Description of the research

The Osterberg cell, named after its inventor, Jorj O. Osterberg, entirely replaces the traditional jack and reaction frame system. The shaft load is applied through an expandable jack and load-cell cast within the test shaft, attached to the reinforcing cage (figure 1) [11].

The Osterberg cell is very simple mechanically, and made of a metal piston and cylinder that create an expandable chamber holding pressurized oil or water. The piston and cylinder are each welded to a 50 mm steel plate whose larger diameter is almost equal the test shaft. The pressurized oil acts on the piston, and taking into account that the piston is usually not less 800 mm in diameter, the Osterberg cell can apply relatively large loads for low hydraulic pressures. Loads of more than 2700 tonnes can be reached with the largest cells [12, 13].

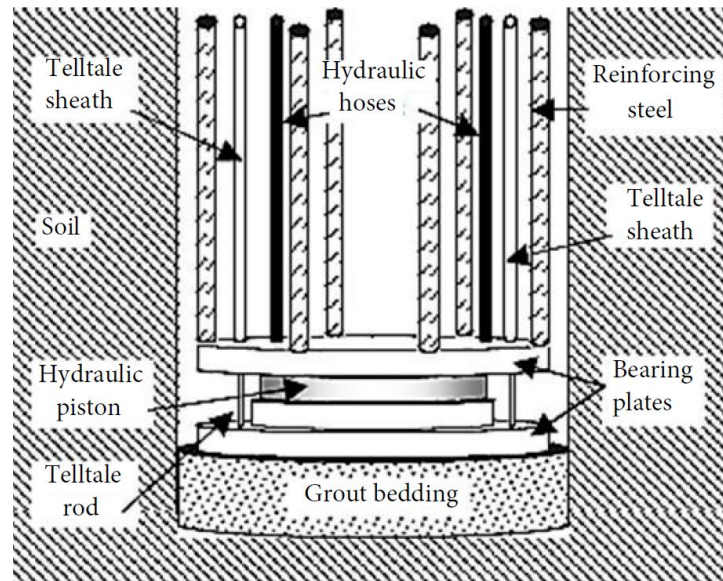


Figure 1. Schematic of an Osterberg cell load-test jack (note that the typical helical reinforcing steel has been omitted for clarity) [11]

Once the concrete has hardened, the jack is pumped up, creating both upward and downward forces in the shaft. Depending on where the cell is placed in the shaft, load tests can be performed to separate and measure several important parameters. For example, if the Osterberg cell is placed at the bottom of a shaft, the upward force enables measurement of the side friction on the shaft, while the downward force enables measurement of the end-bearing capacity of the soil.

In soft soils where bearing capacity at bottom is not expected, the Osterberg cell can be placed somewhere towards the mid-portion of the shaft, and thus use the side friction on the lower portion of the shaft for reaction against which to create the upward force in the upper portion of the shaft. The effective side friction can be measured this way [14].

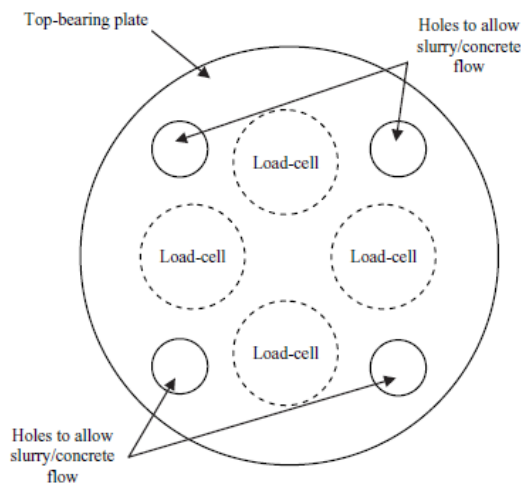


Figure 2. Plan-view of multiple Osterberg cells for large-diameter shaft load tests [11]

For larger-diameter shafts, more Osterberg cells can be installed between the one pair of bearing plates (figure 2). The largest capacity achieved by this way at the present time is more than 278 MN [11].

Another advantage of the bi-directional load test is that if the shaft tested is a production shaft and is proven acceptable, the Osterberg cell can be flushed out and pumped full of grout to become an integral part of the shaft, thus qualifying as a truly nondestructive test technique.

One of features of Osterberg load cells is that they are hydraulic jacks and are mounted inside the frame, which is when put into the borehole and filled with concrete. Through the entire length strain gauges, movement and deflection transducers are installed. After testing, the pile can be used as ordinary.

This method can be connected with almost any existing construction normative documents, so it can be easily integrated [15 - 17].

Scheme of making load test using Osterberg method for 2

cells:

1. Production of pile with frame with load cells and transducers, and keeping concrete for designed strength;

Technology of installation of bored pile with Osterberg cells:

- mounting of the cells, transducers, strain gauges and, if needed, tubes for acoustic testing;
- boring of a borehole;

- installation of the frame into the boring hole, welding of different parts of the frame, taking out of strain gauges and cell cables on surface;
 - filling the bored hole with concrete;
 - keeping the pile unloaded until the concrete will get enough strength for testing using Osterberg method.
2. Opening of the lower load cell and measurement of end bearing capacity (figure 3);
 3. Draining of the lower cell and opening of the upper load cell. Measurement of skin friction of the middle part of the pile;
 4. Closing of the lower load cell and opening of the upper cell. Measurement of skin friction of the upper part of the pile;
 5. Analysis of the received data.

Analysis of the received data is similar to the one we get in standard pile testing with vertical load with the only difference that in Osterberg method we get 2 curves- end bearing capacity and skin friction (Fig.4).

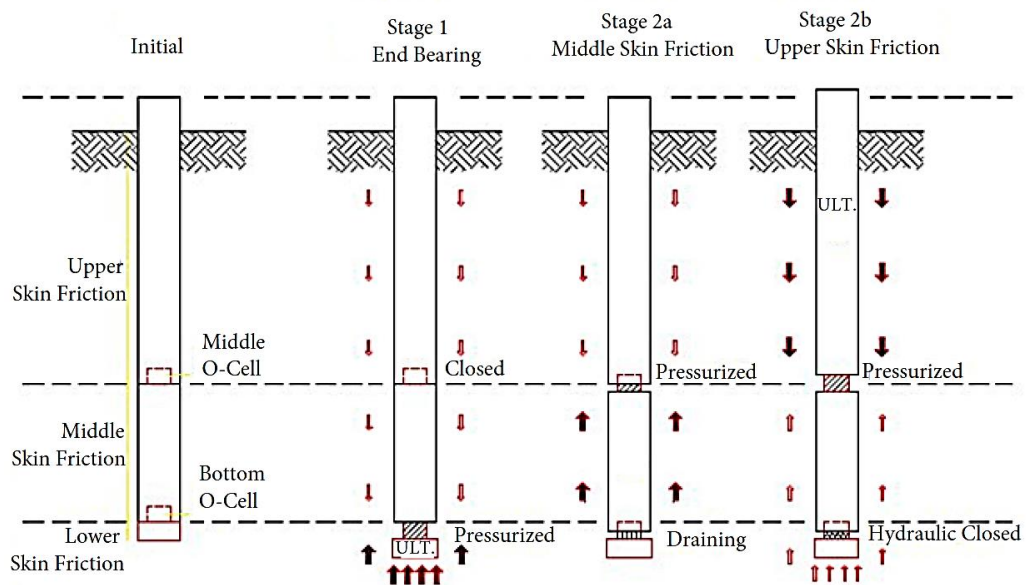


Figure 3. Multi- level O-cell testing [17]

Loads on the load cell apply in opposite directions. Loads from the top and from the below counteract to the load on the cell. Therefore, it can be presumed that the load cell does not apply any additional load to the upward direction until force of its expansion will not exceed weight of the pile over the load cell.

In order to determine skin friction bearing capacity you need to deduct weight of the moving part of the pile from load on the upper cell.

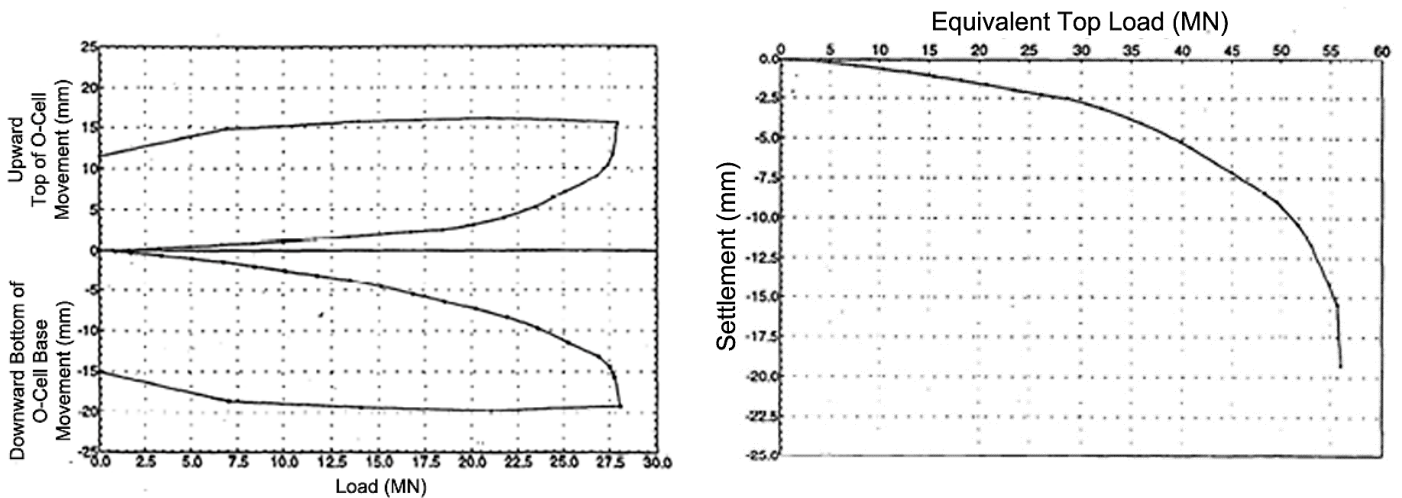


Figure 4. Load-Movement and Load- Settlement curves [17]

In order to make equivalent curve to the standard vertical load test it is needed to sum the end bearing capacity and the skin friction at every point. Insufficient points can be received by interpolation [17 - 19].

The more loads (so bigger anchor constructions in standard load test) the more economical applying of load test with hydraulic jacks will be in comparison with standard vertical load test. In present time this technology is usually applied to boring piles of big diameters (more than 800 mm) and to foundations like barrettes [17 - 19].

Conduction of tests with hydraulic jacks and pile segmentation is obstructed or even impossible in wooden piles, inclined piles and piles perceiving horizontal loads.

Generally high capacity bored piles in combination with expensive testing by vertical load more than 100MN make such tests utterly expensive and unprofitable. Static tests using Osterberg method allow reaching high loads with negotiable price and become a good alternative for bored pile testing.

Small area of working zone in comparison with other testing systems with static load (tests can be conducted inside buildings, on narrow median strips of roads and on sea platforms).

Characteristics of piles after testing with load cells are close to piles, which were not exposed testing, because residual stress in pile is less than the ones, which are left after applying full vertical load in standard tests [20 - 23].

5. Conclusion

Advantages of load cells are:

- Economy: The Load cell test is usually less expensive to perform than a standard static test despite sacrificing the Load cell. Savings are realized through reduced construction time and capital outlay for a test, no top-of-pile reaction equipment requirements and less test design effort. Load cell tests are typically 1/3 to 2/3 the cost of conventional tests. The comparative cost reduces as the load increases [17]
- High Load Capacity: Very high capacity loading is also possible for large driven piles
- Shear/Bearing Components: The Load cell test automatically separates the side shear and end bearing components. It also helps determine if construction techniques have adversely affected each component.
- Improved Safety: The test energy lies deeply buried and there is no overhead load
- Reduced Work Area: The work area required to perform a Load cell test is much smaller than required by a conventional load system.
- Over-water and Battered Shafts/Piles: testing over water or on a batter pose has no special problems for Load cell testing. [24]
- Static Creep and Setup (Aging) Effects: Because the Load cell test is static, and the test load can be held for any desired length of time, the Engineer also obtains separate data about the creep behavior of the side shear and end bearing components [19]

Limitations of the Osterberg cell test:

- Advance Installation Required: With bored piles and most driven piles, the Load cell must be installed prior to construction or driving.
- Balanced Component Requirement: An Load cell test usually reaches the ultimate load in only one of the two resistance components. The test shaft capacity demonstrated by the Load cell test is limited to two times the capacity of the component reaching ultimate. Also, once installed the Load cell capacity cannot be increased if inadequate. To use the Load cell efficiently the Engineer should first analyze the expected side shear and end bearing components and either attempt to balance the two to get the most information from both or unbalance them to ensure the preferred component reaches ultimate first. The introduction of multi-level Load cell testing mitigates this limitation, allowing the Engineer to obtain both ultimate end bearing and ultimate side shear values in cases where the end bearing is less than the side shear [25,26]
- Equivalent Top-Load Curve: equivalent static top load-deflection curve remains an estimate [27].

- Sacrificial Load cell: The Load cell is normally considered expendable and not recovered after the test is completed. However, grouting the cell after completion of the test allows using the tested bored pile or driven pile as a load carrying part of the foundation [17, 23]

Obtained results of the tests with hydraulic jacks show that values of shear friction and end bearing can be used instead of the table values while calculating using SP 24.13330.2011 "Pile foundations". Here with soil coefficient of reliability can be taken in accordance to the conducted tests.

Due to the fact that at present there are no normative documents in Russian Federation for conducting such tests and they are made only by foreign organizations, it is recommended to include this technology into new versions of SP 24.13330.2011 "Pile foundations", so that the Osterberg method could be used by great variety of national organizations [28].

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Методика испытаний буронабивных свай повышенной несущей способности методом Остерберга

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фундамент;
фундаменты глубокого
заложения;
сваи повышенное несущей
способности;

АННОТАЦИЯ

Очевидно, что при высотном строительстве должны быть введены дополнительные требования не только к проектированию, но и к организации, технологии возведения и приемке работ по устройству оснований, фундаментов и подземных частей. Только качественные расчеты и глубокая проработка технических решений позволят создать действительно безопасную конструкцию.

В результате проведенного анализа литературы, по нашему мнению, в связи с появлением новых технологий и типов свай, а также новыми требованиями по увеличению их несущей способности, особенно в высотном строительстве, появилась необходимость применять новые методы испытания свай, позволяющие устройство свай повышенной несущей способности до отказа по грунту. Проведение испытаний свай с помощью гидравлических домкратов и разделением их на сегменты целесообразно для свай с повышенной несущей способностью, когда доведение сваи до отказа по грунту с помощью классических испытаний, предусматриваемых существующей нормативной базой, технически невозможно и/или необходимо использовать громоздкие анкерные конструкции, и проведение испытаний нецелесообразно с экономической и технической точек зрения.

Ячейка Остерберга, названная в честь ее изобретателя Джорджа О. Остерберга, полностью заменяет традиционную систему испытаний с помощью домкрата и опорной конструкции. Нагрузка на тело сваи прикладывается непосредственно внутри сваи с помощью раскрывающегося домкрата и вспомогательных конструкций ячейки нагружения, которые закреплены на арматурном каркасе.

Преимуществом испытания двунаправленной нагрузкой заключается в том, что испытываемая свая может быть использована как рабочая после промывки ячейки Остерберга и закачки раствора в нее. Таким образом, ячейка становится составной частью сваи, что позволяет квалифицировать такое испытание как неразрушимое.

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