СЕКЦИЯ 3. КОНСТРУКЦИИ И ТЕХНОЛОГИИ УСТРОЙСТВА ФУНДАМЕНТОВ В СЛОЖНЫХ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ УСЛОВИЯХ. УСИЛЕНИЕ И РЕКОНСТРУКЦИЯ ОСНОВАНИЙ И ФУНДАМЕНТОВ

УДК 624.138

COMPARISON OF THE PILE TESTING RESULTS ON EXPO-2017 (KAZAKHSTAN)

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Abstract

The article presents loading tests of large diameter and deep boring piles on the construction site in new capital city of the Republic of Kazakhstan. Finally, some recommendations for testing methods suitable for problematical ground conditions of Kazakhstan are introduced. Traditionally, pile load tests in Kazakhstan are carried out using static loading test methods. Static pile loading test is the most reliable method to obtain the load-settlement relation of piles.

Results of static pile tests using the static compression loading test (by ASTM – SCLT), static loading test (by GOST – SLT) and bi-direction static loading test (by ASTM – BDSLT or O-cell) methods are presented in this paper.

Experienced bored piles with length of 31.5 m, diameter 1000 mm. Bi-directional static loading test and Static compression loading test carried out in accordance to ASTM D1143-07 and Static loading test carried out in accordance to GOST 5686-94, (1994).

Hereafter the results of underground testing by the piles with the methods of vertical static testing BDSLT are presented, which had been made on Expo 2017 projects, buildings of Pavilion in Astana, Kazakhstan.

Keywords
Bored piles, testing by static vertical load, load-subsidence, Osterberg or O-cell testing

1. Introduction

The complex of Expo-2017 will comprise 4,000 apartments, a new hotel, a Congress Hall, and an indoor city stretching from the Nazarbayev University to the center of Astana (the Capital of Kazakhstan). The exhibition area will involve the national pavilion of Kazakhstan, as well as international, thematic and corporate pavilions. There will be located shopping malls, entertainment and service facilities as well. The total area of the exhibition stands at 174 hectares (Figure 1).

The symbol of the exhibition EXPO-2017 will be the Kazakhstan platform itself made in the sphere form several floors high with 24000 m^2 in total. The symbol of the exhibition is located in the center of the exhibition village. It is surrounded by international, thematic and enterprise platforms.

The facilities will be maintained with the help of the energy-saving technologies. The buildings will be certified according to the BREEM international standards.

Static testing with Osterberg method (O-Cell testing) was carried out for the test of deep foundations at the site of the construction of this object. Four bored piles were subjected to static tests (O-cell testing– 2 piles and SCLT– 1 pile and SLT by GOST-1 pile).

The target of this tests was obtaining of bearing capacity of piles on problematical soils ground of Expo 2017 (Astana, Kazakhstan) [1-5].

Fig. 1. General Plan Astana City and Plan Expo-2017

Engineering – Geotechnical descriptions of construction sites

At the construction site, complexes of laboratory and field studies of the soil base were also carried out. Figure 2 presents a plan for the location of boreholes on the site of EXPO-2017 [6].

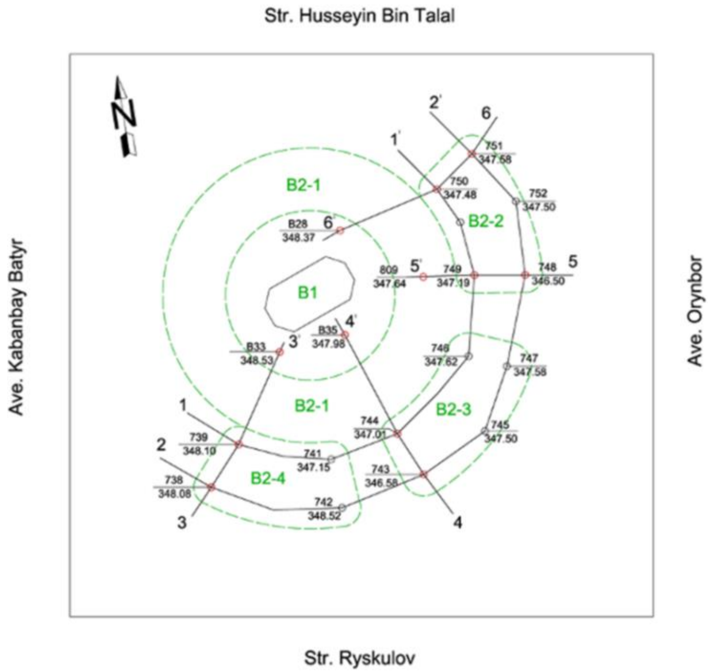


Fig. 2. Plan location of boreholes on construction site of EXPO-2017

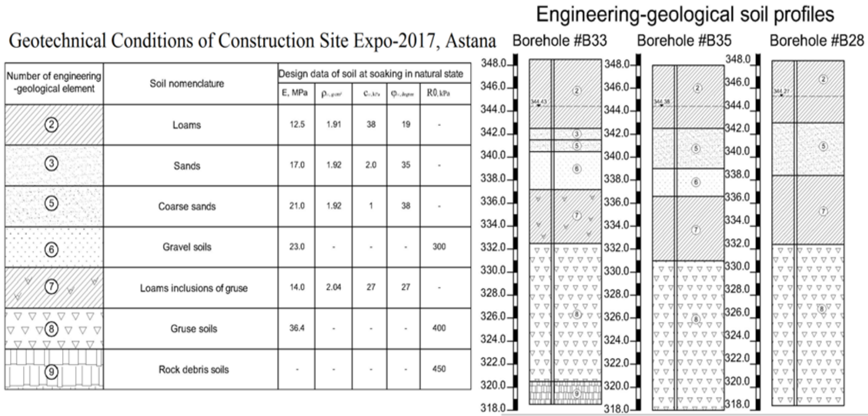
Based on the field description of the soils confirmed by the results of static sounding and laboratory tests, a division of the soils composing the site of prospecting for engineering-geological elements in the stratigraphic sequence of their occurrence was carried out (Figure 3).

EGE-2. Loams of aQII-IV; EGE-3. Sands of medium size aQII-IV; EGE-4. Sands gravelly aQII-IV; EGE-5. Sands large aQII-IV; EGE-6. Gravel soils of aQII-IV; EGE-7. Loams e (C1); IGE-8. Descreen soils e (C1); EGE-9. Crushed earth e(C1).

From the surface, these formations are covered by the soil-plant layer and a layer of loose soils.

According to the drilling data, the groundwater was discovered at depths of 2.30 – 4.20 m (absolute marks of the established level were 343.40-345.05 m).

Figure 3 shows the engineering and geological sections of the EGE and the physical and mechanical characteristics of the soils [1-6].



Number of engineering-geological element	Soil nomenclature	Design data of soil at soaking in natural state				
		E, MPa	ρ	c	φ	R0, kPa
2	Loams	12.5	1.91	38	19	-
3	Sands	17.0	1.92	2.0	35	-
5	Coarse sands	21.0	1.92	1	38	-
6	Gravel soils	23.0	-	-	-	300
7	Loams inclusions of gruse	14.0	2.04	27	27	-
8	Gruse soils	36.4	-	-	-	400
9	Rock debris soils	-	-	-	-	450

Fig. 3. The physical and mechanical characteristics of the soils

Bearing capacity and length of piles needed to be clarified for field testing piles. All experiments were performed with CPT surface.

Soil test at each point of penetration came to the ends under the limit forces on the probe in accordance to GOST 19912-2001 (2001) [7]. The bearing capacity of the pile with cross-section 30x30 cm on the results of CPT:

When projecting it is recommended to accept the following norm values of bearing capacity of piles (pile cross-section 30x30 cm):

– at the depth of 6,0 m bearing capacity 397 kN;

– at the depth of 7,0 m bearing capacity 803 kN;

– at the depth of 7,2 m bearing capacity 887 kN.

The bearing capacity of piles is given without regard to the safety factor for the ground, which is equal to 1.25.

Static tests in accordance with the requirements of GOST

Static tests of soils for bored piles are carried out in accordance to GOST 5686-94 [8]. Test was carried out after the pile concrete strength had attained more than 80% of the design value.

As part of the installation for soil testing, static pressing forces should include equipment:

– device for pile loading (jack);

– supporting structure or platform for perceiving reactive forces (for example, a system of beams with anchor piles or a platform);

– device for measuring the settlement of piles during the test (reference system with measuring instruments).

Before starting the tests, the wire should be subjected to preliminary stretching for two days with a load at least four kilograms. During the tests, the load on the wire should not be more than one and a half kilograms. Limits of measurement and the price of division of pressure gauges used to determine the load on the pile during testing are selected depending on the greatest load on the pile provided by the test program, with a margin of at least 20 percent. Loading of the tested pile is performed evenly, without impacts, by load stages, the value of which is set by the test program, but it is taken no more than 1/10 of the maximum load on the pile specified in the program. When the lower ends of the field piles are buried into coarse-grained soils, gravel and dense sands, and clay soils of solid consistency, the first three load stages are assumed to be equal to 1/5 of the maximum load in the program. At each loading stage of the full pile, the reports for all strain gauges are taken in the following order: zero report – before loading the pile, the first report immediately after the load is applied, field this consistently four reports with an interval of thirty minutes and then every hour before the conditioned deformation stabilization .

For the criterion of conditional stabilization of deformation during testing by the natural pile, the speed of the pile sediment at a given loading stage is assumed to not exceed 0.1 mm in the last 60 minutes of observation if sandy soils or clay soils lie from the hard to the turgid consistency under the bottom of the pile, the bottom end of the pile lies clay soils from the fleshy to the flowing consistency, then two hours of observation. The test load of the field pile shall be adjusted to a value at which the total pile residue is not less than forty mm. When the lower ends of the field piles are deepened into coarse – clastic, dense sandy and clay soils of solid consistency, the load should be brought to the value provided by the test program, but not less than the one-and-a-half pile load-bearing capacity determined by calculation, or the design pile resistance of the material [8].

The unloading of the pile is made after reaching the greatest load with feet equal to twice the level of loading, through one step, with the holding of each stage for at least fifteen minutes. Reports on the deflectometer for strain measurement are taken immediately after each discharge stage and after fifteen minutes of observation. After full unloading (to zero), the piles should be monitored for elastic Settlement for 30 minutes with sandy soils under the lower end of the pile and sixty minutes in clay soils, with reports removed every fifteen minutes. During the test, a log is kept, and the results of the pile test with piles are made out of the graphs of the dependence of the pile sediment on the load-sludge load and the deformation measurements in time along the loading stages.

The bearing capacity of the tested piles with static vertical-pressing forces, at the above construction site, was 12000 kN (Figure 4).

The calculated permissible vertical-punching load on the pile, taking into account the safety factor γ_k = 1.2 according to paragraph 3.10 of SNiP RK 5.01-03-2002 "Pile foundations" [9], it is recommended to take equal 10000 kN.

Pile Static Compression Load Test by ASTM (SCLT method)

Static compression loading testing was carried out in accordance to ASTM D 1143 [10].

Vertical static loading of piles using the SCLT method is one of the most widely used field test methods for soil used to analyze pile bearing capacity. In the first cycle, the experimental pile was loaded to 100% of the design load, in the second cycle to 200% (12,000 kN). The holding time of intermediate loading stages was 30 minutes, unloading – 20 minutes. The time for maintaining peak loads was 120 and 240 minutes, respectively.

The bearing capacity of the tested piles with static vertical-pressing forces, at the above construction site, was 12000 kN (Figure 4). It should be noted that even with a maximum test load of 12000 kN, only the elastic operation of the pile in the ground is manifested, as evidenced by a slight residual soil settlement after unloading, which is 1.4 mm.

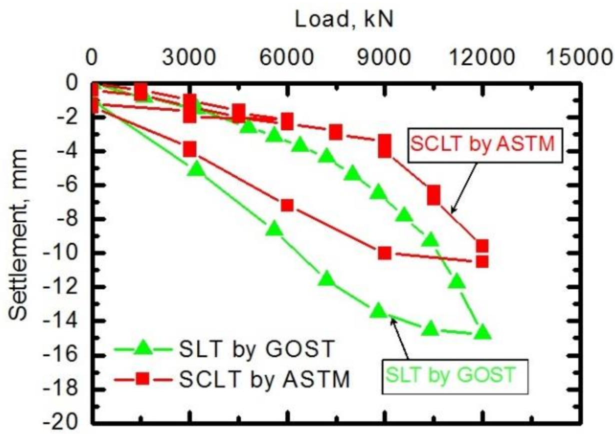


Fig. 4. Results of static loading tests (SCLT and SLT)

Method O-cell piles static test in accordance with ASTM

Pile tests by the Osterberg method are carried out at the pre-project stage, before the design and mass penetration of the piles begins. The method makes it possible to separately determine the bearing capacity of the ground along the tip and along the lateral surface of the pile. It is usually used for testing large or large drill or ramming piles.

When testing piles using the immersed jack, the O-cell power cell is installed directly into the body of the test pile (Figure 5). The power cell is a system of calibrated hydraulic jacks in a protective casing. It divides the test pile into two elements: the upper one, located above the power cell, and the lower one, located under the power cell [12-13].

The monitored load in the power cell (O-cell jack) is created by the hydraulic pressure from the oil station pump located on the surface and connected to the power cell by the oil pipe. The pressure is controlled by a precision electronic pressure gauge calibrated in the general scheme of the hydraulic system. In the process of increasing the load on the walls of the jack piston, the power cell opens. The result of this disclosure is the Settlement of the upper element of the pile upward and the lower element downward. The Settlement of the upper element is measured by rod strain gages mounted on the upper plate of the jack and by displacement sensors installed in the upper part of the steel pipe. The settlement of the lower element is measured by means of rod strain gages mounted on the lower plate of the power cell (O-cell jack).

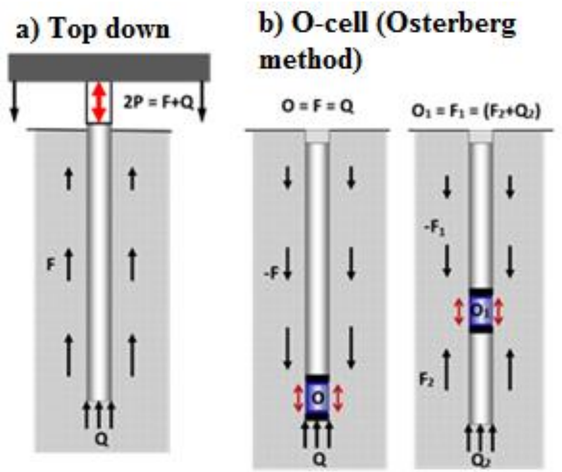


Fig. 5. Scheme test load top downward and bi-directional load [12]

The tests are continued until one of three conditions occurs: it will be that the limit of surface friction or lateral shear is reached; the ultimate load-bearing capacity will be reached; the maximum power of the power cell (O-cell jack) will be reached. Osterberg's method allows testing piles of large dimensions without the use of anchor piles, which reduces costs at the stage of geotechnical surveys.

According to the results of engineering and geological surveys, bored piles 31.5 m long and 1000 mm in diameter were used as foundations. In order to control and evaluate the compliance of the bearing capacity of piles on the ground, the design loads were field static tests by the Osterberg method (Figure 6).

The peculiarity of the O-cell test method is that the load is applied not on the head of the pile, but in the body of the pile, where the jack (power cell) is installed, working in two directions. The power cell (O-cell jack) divides the test pile into two parts: the upper (upper test element – UTE) and the lower (lower test element-LTE). The power cell (O-cell jack) is a system of calibrated hydraulic jacks combined into one module. The hydraulic jack is installed at a depth of ½ the length of the pile – 16.8 m.

The power cell is connected by hydraulic hoses to the hydraulic pump located on the ground surface [12-14].

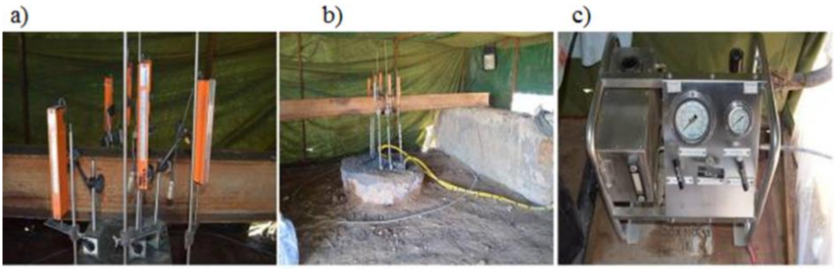


Figure 6 – Testing of piles by static load using the O-cell method:
a – fixing the displacement sensors; *b* – an experimental pile and a reference system
c – hydraulic system (O-cell jack) [12-14]

When designing the O-Cell test, special attention should be paid to the study of the geotechnical structure of the soil massif of the construction site, since the location of the jack in the body of the pile depends on the accuracy of the survey data, in particular the results of assessing soil resistance. The correct decision to place the jack affects the quality of the tests carried out, since the differentiated determination of the load-bearing capacity components (along the lateral surface and below the lower end) is reduced to the correct selection of an equal ratio of the lateral resistance of the soil along the upper element to the resistance below the lower end of the lower element of the experimental pile.

Results of field trials using the Static Load Test and Osterberg methods

Figure 7 shows a comparison of the test results: the "load-sludge" curve obtained by the SCLT method and the equivalent "load-settlement" curve determined by the O-cell method.

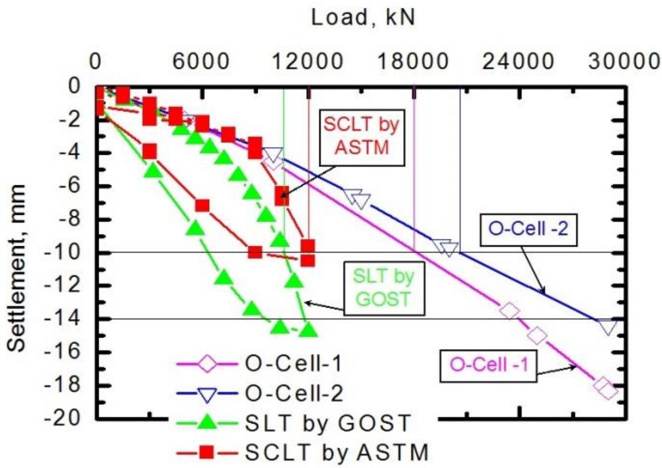


Fig. 7. Comparison of test results carried out by SCLT, SLT and O-cell methods [12-14]

Conclusions

The overlay of the curves showed that the convergence of the graphs is observed only at the initial stage of loading, then a change in the trajectory of the SLT curve, characteristic of the creeping stage of soil resistance, is observed, whereas the O-cell curve (at this stage of loading) is more characteristic of the elastic resistance of the soil.

According to the results of the SCLT unloading curve, elastic work of the soil is still evident. The reason for the abrupt change in the trajectory of the SCLT curve, which is not characteristic of the elastic work of the ground, is the holding time of the loading stages (lower compared to the O-cell test method), which can also explain the almost completely elastic work of the soil during O-cell tests.

When testing piles using the SLT method "from top to bottom", a design load of 6000 kN corresponds to a draft of 2.09 mm, a maximum test load of 12000 kN is a draft of 10.51 mm. It should be noted that even with the maximum test load, only the elastic operation of the pile in the ground is manifested, as evidenced by a slight residual soil sediment after unloading, which is 1.4 mm.

When testing piles using the O-cell test, a maximum test load of 29000 kN corresponds to a draft of 18.35 mm (for the PTP-1 pile) and – 14.40 mm (for the PTP-2 pile). During the testing of the piles, both elastic and plastic deformation of the soil was observed, due to a greater test load on the pile than in the SLT method.

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ПРИМЕНЕНИЕ ДОБАВОК ФЕРРОМАТЕРИАЛОВ ПРИ УСИЛЕНИИ И УСТРОЙСТВЕ ФУНДАМЕНТОВ

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Аннотация

Фундаменты многих исторических зданий, изготовленные из бутового камня, из-за деструкции известкового раствора нуждаются в усилении, которое осуществляют обычно путём инъекции цементного раствора. При производстве работ возникает проблема осуществления контроля качества и, в частности, определения степени заполнения пустот и трещин.