Comparative analysis of different type of piles work in problematical soil ground of Astana (Kazakhstan)

Analyse comparative des divers pieux de fondation dans le sol problématique d'Astana (Kazakhstan)

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ABSTRACT

In this article presented analysis of working different type of piles. Problematical inhomogeneous soil condition of Astana (Kazakhstan) gives us to possibility to consider the work of different type piles in various soil ground, and numerical analysis helps us to understand difficult soil-pile interaction.

We carried out full-scale load tests of piles (static and dynamic load tests), comparative economical analysis, pile installation technology, numerical analysis and specified disadvantages and advantages of each type of piles in problematical soil ground of Astana. Recommendations for using of different type of piles in inhomogeneous soil condition are given.

Using in-situ tests of the piles results of the bearing capacity definition more than 30 construction sites, it was carry out the estimation of the authenticity and reliability of each methods.

RÉSUMÉ

Dans cet article on fait l'analyse du fonctionnement des divers pieux de fondation. Les conditions de sol hétérogènes problématiques d'Astana (Kazakhstan) nous fournit la possibilité d'envisager le fonctionnement des divers pieux dans les conditions de sol variées. L'analyse digitalisée nous aide à comprendre l'interaction compliquée de « pieu-fondation ».

Nous effectuons des essais des pieux sur le chantier d'exploration (par les charges dynamiques et statiques), l'étude (faisabilité) économique comparée, l'analyse digitalisée, mettons au point la technologie de l'enfoncement des pieux et définissons les défauts et avantages en terme du comportement de chaque pieu de fondation dans le sol problématique d'Astana. Les recommandations de l'usage des divers pieux de fondation dans les diverses conditions de sol sont citées dans cet article.

Les résultats des essais des pieux sur le site pour définir la capacité portante sur plus de 30 sites de chantier ont été utilisées et également a été effectuée l'estimation de l'authenticité et de la fiabilité de chaque méthode.

Keywords: foundation pile, load tests, steel pile, geotechnology.

1 INTRODUCTION

Nowadays pile foundations have been used in a wide range as in construction buildings and industrial buildings in Kazakhstan, CIS and all over the world. Very high temp of constructing and the appearance of very tall buildings in Astana with its complicated soil conditions required mainly use pile foundation.

At the same time, for the purposes of such kind of tasks and analyses of interactions between high level buildings and pile foundation using modern computer program should be taken to account.

Tendency to the development and improvement of new constructions quality with the account of time, energy, labor force and money save is becoming one of the issues in implementation of different projects between customers and performers.

At present time construction of buildings in new capital of Kazakhstan of Astana, apply piles: precast square section; bored (with casing, through technology of CFA and by displacement soil) and steel "H" sections. Steel "H" piles for the first time are used for construction of Kazakhstan. The given piles have been accepted by designers at construction of Embassy of the USA in Astana (ASTM D 1143-81).

Modern engineering experience has developed some new technologies as Full Displacement Piling (FDP) technology which has started adoption in western countries.

Figure 1. New Area of the New Administrative Center

Figure 2. The Islamic cultural center

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Figure 3. Palace of the Peace

Figure 4. Entertainment Centre "Khan Shatyry"

Figure 5. Three apartments of “Severnoe Siyanie”

Figure 6. Three apartments of “Emerald Towers”

2 ENGINEERING-GEOLOGICAL CONDITIONS OF THE SITE

2.1 *Construction site of the USA embassy*

The site of researches for construction is on the Southeast side of Astana the capital of Kazakhstan, on the right side of Esil river. The territory of the city of Astana is located on the Kazakh Shield on which the tectonic activities, that’s why it appears to be safe for the construction purposes.

In geological structures of a site of researches take part: alluvium the modern adjournment presented by loams, clay with lenses of gravel sand and loam, gravel soil; eluvial the formations presented by loams with inclusions gruss and rubble, sandstones and siltstone, gruss-rubble soil; and also eluvial formations middlejurassic the breeds, presented by aleurolites. All the before mantioned sediments are covering by a soil-vegetative layer from above.

Results of physic-mechanical properties of soil the bases of construction site are resulted from top to down in Table 1.

Table 1. Physic-mechanical properties of site soil

Type of Soil	E, MPa	C, kPa	φ, deg.	R_o, kPa	ρ, g/cm^3
Loam and clay	5.1	27	19	-	1.89
Gravel	-	-	-	350	2.05
Loam	21	59	23	-	1.98
Gruss-rubble	-	-	-	400	2.15
Aleurolites	Compression strength 15 MPa				2.47

2.2 *Construction site of two apartments of Trade & Entertaining Centre “Khan Shatyry”*

The site for construction is on the Southeast side of Astana, on the left side of Esil river.

On the basis of the visual description of grounds and to the data of the skilled field works confirmed with results of laboratory researchers, division of grounds, researches composing the site on engineering-geological elements in Table 2.

Table 2. Physic-mechanical properties of site soil

Type of Soil	E, MPa	C, kPa	φ, deg.	ρ, g/cm^3
Fill-up soil	-	-	-	1.90
Loamy soil, water saturated	7.5	14	19	1.98
Gravelly sand	21	1	38	1.92
Gravel soil	22	-	-	2,00
Loamy soil with inclusion gruss and gravel	13	12	27	2.47

3 FEATURES OF APPLICABLE PILES

3.1 *Steel pile*

Steel piles “H” sections of type HP12x74 (HP305x110), became made from high-strength low alloy colombia-vanadium of a class 50 (345) according to ASTM A572 Grade 50 (ASTM A572/A572M-04). The maintenance of chemical elements in structure of steel of a metal pile are resulted in Table 3.

Table 3. Chemical compound of steel of a metal pile

No	Chemical element	Designation	The maintenance, %
1	Carbon	C	min 0,08
2	Iron	Fe	98
3	Manganese	Mn	1.35
4	Fluorine	P	max 0.04
5	Sulfur	S	max 0.04
6	Silicon	Si	max 0.04

On an edge of a pile pile shoe from the strong steel tips HP-7780-B made Associated Pile and Fitting Corp (Clifton, state of New Jersey) weld.

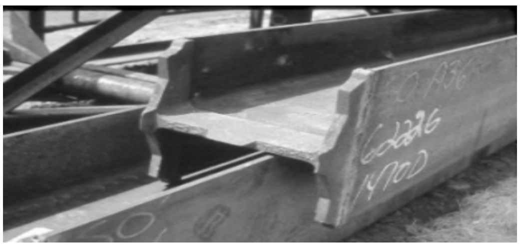

Figure 7. Steel pile with a steel tip

3.1.1 *Influence of corrosion on steel piles*

Corrosion in soil, water or moist out-door environment is caused by electro-chemical processes. Different types of corrosion can occur in soils, such as soil corrosion, galvanic corrosion and current leakage corrosion. In the case of steel piles and steel sheet piles, soil corrosion is most important (Göran Camitz 1980).

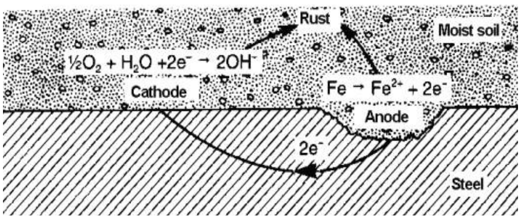

Figure 8. Electro-chemical reaction in one corrosion cell

Soil corrosion is caused primarily by diffusion of oxygen from the soil to the steel surface. Corrosion decreases with depth on piles or sheet piles in stationary, fresh water or salt water, due to the reduced oxygen content. The results from the investigations in soil show consistently that the location of the ground water level, and thus the access to air has a dominating influence on the corrosion of steel piles. Below the ground water level, the average corrosion is normally small, rarely in excess of 20 mm/year and often significantly lower.

In this connection, up to the device of piles hole in diameter of 600 mm by depth of 1.5 m. These hole after driving piles have preliminary been drilled were concreted, for restriction of access of air (oxygen) on a surface of steel through a ground.

3.2 *Bored pile through FDP technology*

This technology includes formation of a hole up to necessary depth by means special cone-shaped boring tool, without excavation due to its compacting (lamination) a bottom of the hole and its lateral surface. Then concreting of this hole from bottom, by continues feeding of plastic concrete under pressure by means of concrete pump through the aperture in the boring tool, up to its full filling with concrete. Then installation reinforcing cage of the corresponding length. The shape of the pile is fulfilled in 4 ways (Figure 9).

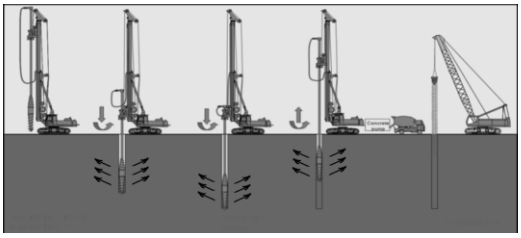

Figure 9. Bored pile through FDP technology

First way: Installation of the boring tool on a point.

Second way: Performance of a hole without of excavation of a soil due to its compaction (lamination).

Third way: Extraction of the boring tool with simultaneous filling a hole by concrete through an aperture the boring tool.

Forth way: Installation of spatial reinforcing cage.

4 INVESTIGATION METHOD

4.1 *Steel pile*

Before driving test steel piles have been marked every of 25 cm on all length (L=12.0 m).

For driving steel piles used pile driving rig Junttan PM20 with hydraulic hammer HHK-4A part of blow with weight 4.0 tons.

4.1.1 *Carrying out of dynamic tests of the first stage*

In the first stage, steel piles were driving according to preliminary criteria for a stop: on 600 kN working loading, refusal of a pile should be equal 1.25 cm; on 400 kN working loading, refusal of a pile should be equal 1.67 cm.

Nine test steel "H" piles were subjected to dynamic tests. Embedded depth of "H" pile and average refusals are resulted in Table 4.

Table 4. Results of dynamic tests of the first stage

Number of pile	Embedded depth, m	Design load, kN	Refusal of pile at driving, cm
LT-1	7.00	600	1.00
LT-9	9.25	600	1.25
LT-4	8.00	400	1.56

After "rest", "H" piles driving with such refusals were tested by static loadings.

4.1.2 *Carrying out of static tests of the first stage*

Static tests were spent according to requirements of Standard ASTM D 1143-81 and of GOST 5686-94, as object of research is the Embassy of the USA (Bozozuk, Keenan and Pheeney 1979).

Steel piles should be tested for a minimum 200 design working loadings, on 600 kN design loading to apply pressing loading 1200 kN, and on 400 kN accordingly 800 kN.

At static tests the following equipment was applied:

- hydraulic jack SMJ-158A - 200 ton;
- caving in-measurers of the type 6ПАО.

The pressure in the jack was created with the help of manual oil pump station MNSR-400 with power up to 800 kg/cm², the moving of steel piles was fixed by caving in-measurers of the type 6-PAO, which were positioned on both sides of unmovable bearings with the benchmark system.

The first count out, performed right after putting the loading, then consequently 4 counts out with an interval of 15 minutes, 2 counts out with an interval of 30 minutes and further for every hour until the conditional stabilization of deformation. Loadings were created by steps on 150 kN.

For the criterion of conditional stabilization of deformation was taken the speed of settlement of boring piles on the given stage of loading that did not exceed 0.1 mm during the last 1-2 hours of observation. Steel piles required reactive efforts. Reloading was conducted in stages 300 kN.

Carrying out of static test and results are shown in Table 5.

Table 5. Results of static tests of the first stage

Number of pile	Embedded depth, m	Design load, kN	Refusal of pile at driving, cm	Settlement, mm	Applied load, kN
LT-1	7.00	600	1.00	43.03	900
LT-9	9.25	600	1.25	52.55	900
LT-4	8.00	400	1.56	39.88	600

Diagrams of dependence of loading and settlements of steel pile by results of static tests of the first stage in Figure 10.

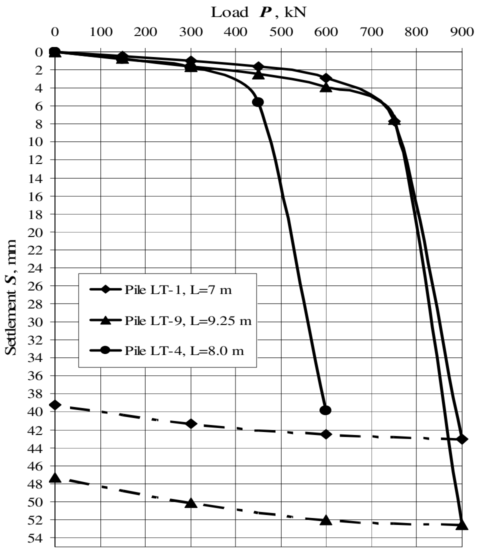

Figure 10. Graph of dependences of settlements *S* from the loading *P*

The further test of other six piles had no sense as results of static tests have shown not satisfactory bearing capacity, and the decision about extension lengths of a pile was accepted.

4.1.3 *Dynamic tests of the second stage*

In the second stage steel piles driving, after extension lengths of a pile by electric welding, according to criteria for a stop:

- for 600 kN, refusal of 0.33 cm (25 cm/75 blows);
- for 400 kN, refusal of 0.83 cm (25 cm/30 blows).

4.1.4 *Static tests of the second stage*

After extension lengths of piles and repeated driving them before refusals resulted above (item 4.1.3.), have been lead static tests of the second stage, their results are resulted in Table 6.

Table 6. Results of static tests of the second stage after augmentation

Number of pile	Embedded depth, m	Design load, kN	Refusal of pile at driving, cm	Settlement, mm	Applied load, kN
LT-1	9.75	600	0.31	4.66	1200
LT-9	12.75	600	0.27	4.96	1200
LT-4	11.25	400	0.78	3.38	800

4.2 *Carrying out of static tests of the Bored pile through FDP technology*

The technology of static loading test of bored piles was done in accordance with the requirements of GOST 5686-94, i.e. according to the GOST requirements bored pile is tested after reaching its concrete strength of precast pile till 80% from total strength and for driving piles the test is provided after 6 day “rest”. Then both piles are tested on their concrete body integrity with the help of computer testing - FPDS SIT (Foundation Pile Diagnostic System Sonic Integrity Testing).

The loads were made by three 2000 kN hydraulic jacks DG200P150 rest on anchoring supporting stand. The reaction force took by forth anchoring bored piles (Zhusupbekov and Ashkey). The pressure in the jack was created with the help of manual oil pump station NRG-8080, load was controlled with the technical monometer MA100BU63.

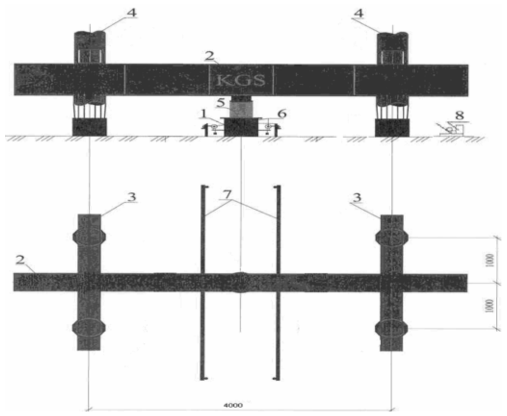

Figure 11. The scheme of anchor-persistent test bench: 1 – FDP pile, 2 – basic beam, 3 – auxiliary beam, 4– pipes for welded seam, 5 – jack, 6 - caving in-measurer, 7 - benchmark system, 8 – pump with manometer.

The first count out – right after putting the loading, then consequently 4 counts out with the interval 15 minutes, 2 counts out with the interval 30 minutes and further in every hour till the conditional stabilization of deformation. For the criterion of conditional stabilization of deformation was taken the speed of settlement of bored pile on the given stage of loading that did not exceed 0.1 mm during the last 1 hour of observation.

Table 7. Results after static load tests

Type of pile	Number of pile	Diameter or section, cm	Pile length in soil, m	Maximal load, kN	Settlement, mm	Bearing capacity, kN
CFA	№1	60.0	16.5	4280	40.00	3798
FDP	№2	41.0	16.5	2996	66.64	2200
Driven pile	№3	30x30	11.5	1070	6.70	1070

Since maximum pile settlements did not run up to the ultimate settlement value being 16 mm, the maximum imposed loads were taken as the pile bearing capacity (Bartolomey, Omelchak and Yushkov 1994).

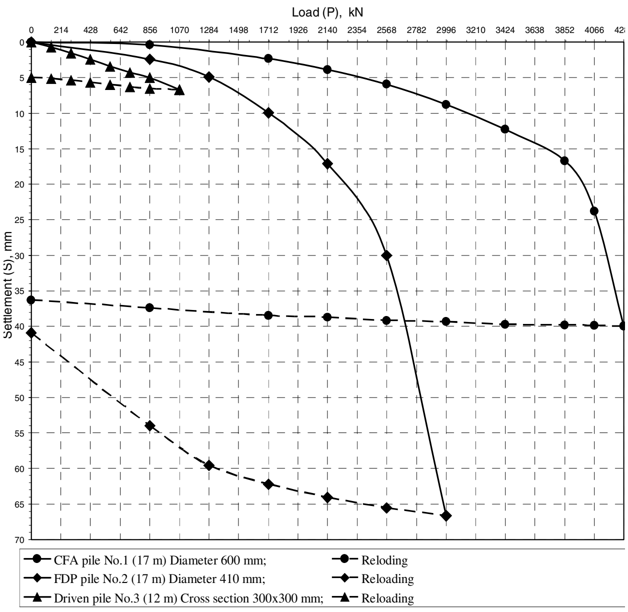

Figure 12. The comparing curves of piles dependences of settlements *S* from the loading *P*

5 CONCLUSIONS

By the obtained results it was concluded: for the high-altitude constructions it is better to use continuous flight auger piles (CFA) and drilling displacement piles (DD piles), and for the other buildings driving piles, precast concrete and steel H-piles are allowable. By the results it was found that the value of the bearing capacity obtained by dynamic load tests less of 10-20 % of the value of the bearing capacity obtained by static load tests.

Comparative analysis had shown the significant different of the settlements which was determinates by the results of the site exploration and by the results of the in-situ tests. The settlement obtained by numerical analysis was significantly bigger than the settlement obtained by the results of the in-situ static load tests.

REFERENCES

ASTM A572/A572M-04. 2004. Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel.

ASTM D 1143-81. 1981. Standard Test Method for Piles Under Static Axial Compressive Load.

Bartolomey, A.A., Omelchak, I.M. & Yushkov, B.S. 1994. “Prognosis of settlement of pile foundations», Moscow, p. 302.

Bozozuk, M., Keenan, G.H. & Pheeney, P.E. 1979. Analysis of Load Tests on Instrumented Steel Test Piles in Compressible Silty Soil. Behavior of Deep Foundation, ASTM STP 670. Raymond Lundgren, Ed., American Society for Testing and Materials, pp. 153-180.

GOST 5686-94. 1994. Soils. Field test methods by piles. M.: Standards Publishing House.

Göran Camitz. 1980. Corrosion and protection of steel piles and sheet piles in soil and water. Excerpt and translation of Report 93, Swedish Commission on Pile Research.

Zhusupbekov, A.Zh. & Ashkey, Y. Geotechnical Problems of Mega Projects on Difficult soil Ground of Kazakhstan. The Proceeding of the International Geotechnical Simposium “GEOTECHNICAL ENGINEERING FOR DISASTER PREVENTION & REDUCTION”, 24-26th of Yuly, 2007, Yuzhno-Sakhalinsk, Russia, pp. 116-122.