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COMPLEX OF STATIC LOADING TESTS OF BORED PILES

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ABSTRACT: This paper presents the complex analysis of diverse field loading tests of ten large diameter deep bored piles on CFA technology at the Karachaganak Processing Complex (KPC), Aksay, Kazakhstan. On the basis of core sample analysis and seismic studies, the geological conditions of this field are varied and complicated. According to the project design, the field tests of CFA bored piles with diameter 600 mm, length from 15.51 m to 21.85 m were performed by two static laterals, four static tensile and four static compression pile loading tests. Static loading tests applied a load to a deep-foundation element gradually for measuring foundation settlement. The static loading tests were performed by ASTM D1143, ASTM D3689, and ASTM D3966. In this paper are shown the load-settlement and the load-displacement diagrams from those field tests which give the possibility to identify the bearing capacity of piles at this ground. The analysis showed that the bearing capacity of bored piles with different lengths corresponds to the design requirements.

Keywords: Pile test, CFA bored pile, STPLT, SCPLT, SLPLT

1. INTRODUCTION

Loading tests used for deep CFA piles at the Karachaganak Processing Complex (KPC) Gas Debottlenecking Project near Aksay, Kazakhstan for more shipments platforms. The Karachaganak field is one of the world’s largest oil and gas condensate fields located in northwest Kazakhstan and covering an area of more than two hundred eighty square kilometers. By the requirements of the design documentation, for pile foundations on weak soils were performed the accessible testing methods comply with these requirements and presented the results of testing.

Applied load and head movement measured for static axial compression and tension load tests. Applied loads are determined using a load cell and hydraulic jack pressure. The foundation’s head movement measured using digital or mechanical dial gages, a number of types of displacement transducers, string potentiometers, or a combination of these devices. The applied load and head movement are plotted and interpreted to define the foundation’s geotechnical load.

In this paper provided the results of static tests of soil, and comparing of bearing capacities by results of static tests. Static tests of piles on the vertical load, being the simulation which is the brought most close to the reality step loading of a pile in the course of construction exponentiation, show real system behavior "pile - soil" in specific geological conditions. Test results are of great scientific interest based on which are made analytical researches and detections of empirical regularities. In relatively recent times, pile testing revolutionized largely because of high-powered computers. Fifteen to twenty years ago, testing options were restricted to static loading tests; with some costly and slow forms of integrity, testing was available. Now, a variety of tests is available to estimate or measure pile resistance, together with numerous methods available for quick and economically testing piles for structural integrity.

2. ENGINEERING-GEOLOGICAL CONDITIONS OF THE CONSTRUCTION SITE

Sediments in the five hundred thousand square km basin are up to twenty-two km thick in places. The basin subdivided into numerous zones by large salt domes, and the primary salt layer, the Permian Kungurian salt, separates strata vertically into subsalt and suprasalt layers. The basin bounded to the east by the Hercynian Ural Mountains and to the southeast and south by other orogenic belts. In the north, the basin lies on the flank of the Voronezh Massif in the west and the Volga-Ural Platform in the north. Numerous oil and gas fields discovered in this region in addition to Karachaganak, such as Astrakhan, Tengiz and Zhanazhol Fields [1]-[2]. Results of physic-mechanical properties of soil the bases of the construction site are resulted from top to down in Table 1.

The depositional setting of the field is also varied. Based on core sample analysis and seismic studies the following depositional settings identified limestone, talus, normal marine, shallow marine, inner reef lagoon, reef core, relatively deep water, slope, and anhydrite [1-3].

Table 1 Standard and design values of physical and mechanical characteristics of soils

N EGE	Soil Consistency g/cm^3	Specific cohesion MPa	Angle of internal friction, deg.	Modulus of deformation	Design resistance kPa
	ρ	c	ϕ	E	R0
1	1.73	-	-	9.34	400
	1.96	0.006	20	4.4	200
2	1.77	-	-	7.39	400
	1.97	0.008	19	4.78	200
4	1.92	-	-	8.08	400
	2.03	0.015	19	7.10	250
5	1.94	0.029	17	7.59	250
	2.01	-	-	-	-
6	1.96	0.026	18	8.09	250
	2.01	-	-	-	-
7	1.98	0.020	19	8.33	250
	2.03	-	-	-	-

In geological structures of a site of researches, take part:

EGE-1: Loam-heavy, dusty, yellowish-brown, brown color, lumpy, weakly wet, from solid to semisolid consistence, setting;

EGE-2: Clay-light, brownish black, yellowish-brown and brown color, lumpy, weakly wet, from solid to semisolid plastic consistence, setting;

EGE-4: Clay-light, dusty, brown and light brown color, lumpy, weakly wet, from solid to tough plastic consistence;

EGE-5: Clay reddish-brown, dark brown color with black free designs, solid weakly wet, from solid to tough plastic consistence;

EGE-6: Clay-light, dusty, greyish-brown, dun color with free designs of grey color, average density, weakly wet, wet, from semisolid to tough plastic;

EGE-7: Clay-light, dusty, dun, grey, dark grey color, average density, wet, tough plastic.

3. THE PILE INSTALLATION THROUGH TECHNOLOGY CFA

Modern geoengineering face with engineers and designers modern requirements, therefore traditional technologies were replaced by resenting economically, ecologically and energy-efficient technologies, including pile foundation. Pile foundation is a widespread type of foundations on construction sites of Kazakhstan. The expediency of pile foundation explained by the high value of bearing capacity of high-rise buildings. At the same time, settled design Standards is not corresponding with newly emerged technologies, because of the absence any recommendation for new pile design. CFA pile is a type of drilled foundation in which the pile drilled to the final depth in one continuous process using a continuous flight auger. The use of the continuous flight auger rig avoids many of the problems of drilling and concreting piles experienced when using conventional power augers. Installation of CFA pile consists of following steps: placing the boring machine to the boring place; boring the pile hole to the design level; removing the screw with simultaneous concrete filling under the high pressure and replace the boring machine, installation of steel anchor into the pile body with the preparation of pile head. In modern CFA technology, the systematic employment of devices auto-recording the drilling data represent a real breakthrough considering that in the past the CFA method was not accurate, and relied on the operator’s ability: now such devices guarantee the control and recording of the data during the whole construction process. The recorded working data are usually drilling/withdrawal speed, rotation speed, depth, concrete pressure and delivery rate per increment of auger lift during casting [4-5]. The CFA construction sequence is comprised of five stages in Figure 1.

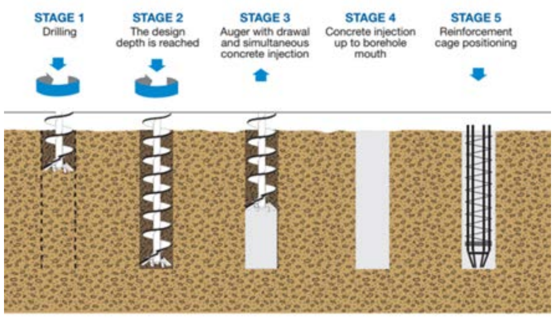

Fig. 1 The CFA construction sequence

Stage 1. The digging tip of the auger is fitted with an expendable ca);

Stage 2. The auger drilled into the ground to the required depth;

Stage 3. Concrete pumped through the hollow stem, blowing off the expendable cap under pressure;

Stage 4. Maintaining positive concrete pressure, the auger withdrawn all the way to the surface;

Stage 5. Reinforcement placed into the pile up to the required depth.

4. STATIC COMPRESSION PILE LOADING TEST

Static Compression Pile Loading Test (further SCPLT) one of the more reliable field-tests in analyzing pile-bearing capacity. SCPLTs carried out for four piles on the construction site (Figure 3). The measured relationships between the pile head load, L, and the head settlement, S, of the test piles a shown in Figure 4.

Fig. 2 Field pile test by SCPLT method

It is seen from Figure 4 that the load-settlement curves of four piles SCPLT-1,-2, -3 and SCPLT-4 are almost identical, having an ultimate shaft capacity of 1050 kN (SCPLT-3 and SCPLT-4), for pile number SCPLT-2 to 1310 kN and for pile number SCPLT-1 to 1975kN [5]-[6].

There are the bored piles with diameter 600 mm and length from 15.53 m to 21.85 m.

Standard – SNiP RK 5.01-03-2002 – ultimate value of settlement of the tested pile is determined as and depending on the category of construction is equal to 16 or 24 mm. The last argument shows the conditional character of SLT method [3-7].

The pressure in the jack was created with the help of manual electro-hydraulic pump station NER -1,6A40T1 with power distribution, the moving of concrete piles was fixed by caving in measurers MA100BU100, which were positioned on the center of unmovable bearings with the benchmark system. For reference beams using two H-beams with h=20 cm and length 5.3 m which bolted with a clamp to screw piles BAU 114*4*2000 drilled in soil with depth 1.5 m [7].

Most of the static pile load tests a performed using reaction systems (see Figure 2). SCPLT is a highly accurate and robust system that enables you to monitor static pile tests whilst also ensuring the safety of site operatives.

This test used to measure the axial deflection of a vertical deep foundation when loaded in static axial compression. This vertical compression pile maintained load test is usually carried out to ensure the structural and geotechnical soundness of the pile and to predict the settlement of other piles.

The usual procedure is to increase the load in stages until the proposed working load and a certain factor of safety is reached and then to unload and to leave the load off until the rise or rebound substantially ceases, the test in standardized by ASTM D1143 [6].

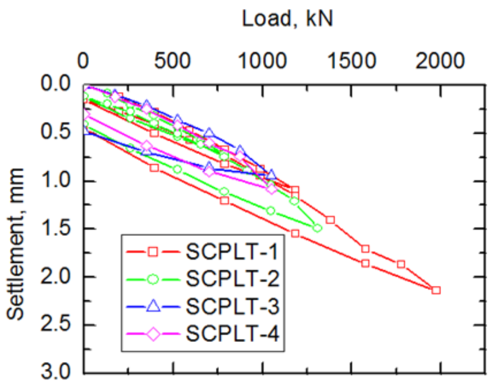

Fig. 3 Results of Static Compression Pile Load Test of piles SCPLT (1, 2, 3, 4)

Vertical static loading of piles using the SCPLT method is one of the most widely used field test methods for soil used to analyze pile-bearing capacity. The pile may be tested in two standards cycles:

- The 1st cycle tests the pile to its 150% of the Design Load.
- The 2nd cycle tests the pile to its 200% of the Design Load.

Static compression pile loading tests were performed on bored piles SCPLT (1, 2, 3, 4) with length from 15.53 m to 21.85 m. In SCPLT tests, piles are performed by two loading-unloading cycles (one cycling load at 1050 kN for pile SCPLT-3,-4 and twice cycling load started from 786 kN to 1310 kN for pile SCPLT-2 and from 1185 kN to 1975 kN for SCPLT-1, respectively). Loading and unloading was carried out in the following sequence (SCPLT-1 and SCPLT-2): 0, 25, 50, 75, 100, 125, 150, 100, 50, 0, 25, 50, 100, 125, 150, 175, 200, 225, 250, 200, 150, 100, 50 and 0% of design [8]-[9].

In the first cycle, the testing piles are loaded to 150% of the design load (786 kN, 1185 kN); at the second cycle, piles tested on 200% of design load (1310 kN, 1975 kN) that shown in Figure 3. The hold time while loading was 60 min; while unloading −15 min. It took 300 min, respectively, to attain peak load [8]-[9].

5. STATIC TENSILE PILE LOADING TEST

Static tensile loading test does not apply concrete and composite piles, restressed reinforced concrete piles without transverse reinforcement bored piles with enlarged base and screw piles. It allowed using the piles with the help of which the soil test was tested with the static top download. The depth of the pile subsidence during a test conducted for the purpose of determination of the negative friction in subsiding soils, apply equally to the distance from the surface of the soil to the depth where the soil additive from its own weight during soaking equal the maximum permissible draft for the planned building or structure. For the criterion of conditional stabilization deformation take the exit velocity of the pile from soil on each stage of the application tensile load must be no more than 0.1 mm in the last 1 hour of observation or pile foundations of buildings and structures (except bridges), and pile foundations for bridge piers - no more than 0.1 mm in the last hour of observation. Load at the control pile test with the tensile load during construction should not exceed the design tensile load on pile indicated in a calculation of the pile foundation [10].

Fig. 4 Static Tension Pile Loading Test in construction site Aksay

CFA bored piles with diameter 600 mm and lengths from 15.51 m to 21.71 m were tested by the static tensile loading test in construction site Aksay (see Figure 4).

Loading and unloading was carried out in the following sequence (for piles STPLT): 0, 25, 50, 75, 100, 125, 150, 100, 50, 0, 25, 50, 100, 125, 150, 175, 200, 225, 250, 200, 150, 100, 50 and 0% of design. In the first cycle, the testing piles were loaded on 360 kN of the design load; at the second cycle - 600 kN. According to STPLT results, the load - settlement diagram had following curves (see Figure 5) [10]-[11].

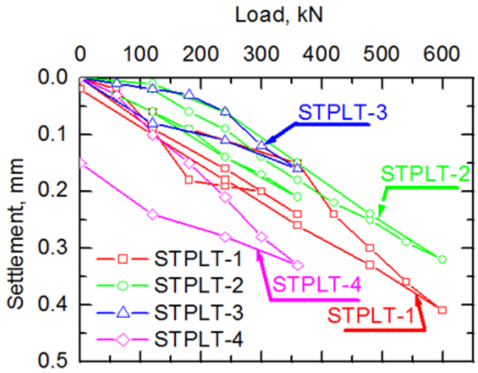

Fig. 5 Results of Static Tension Pile Load Test of piles SCPLT (1, 2, 3, 4)

6. STATIC LATERAL PILE LOADING TEST

This test method covers procedures for testing vertical and batters piles either individually or in groups to determine the load – deflection relationship when subjected to lateral loading. It is applicable to all deep foundation units regardless of their size or method the actual lateral load capacity of the pile – soil system can best be determined by lateral testing. Under the iterative elastic method of analysis, that considers the nonlinear response of the soils, lateral testing combined with proper instrumentation can be used to determine soil properties necessary for the structural design of the pile to resist the lateral load to be applied [12].

Fig. 6 Static Lateral Pile Loading Test in construction site Aksay

Static Lateral loading tests used for CFA bored piles in the construction site of Aksay (see Figure 6). Bored piles with diameter 600 mm and length from 15.51 m to 20.50 m have been executed at the Caspian Sea for more shipments platforms construction site [13]- [14].

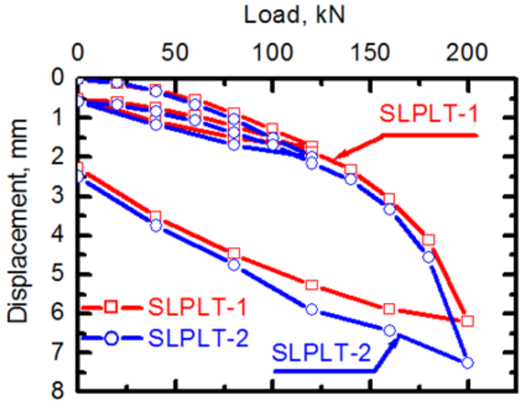

Fig. 7 Results of Static Lateral Pile Load Test (SLPLT-1 and SLPLT-2)

Table 2 presents a comparative analysis of the bearing capacity of piles, obtained by different methods in this research [12-14].

Table 2 Results of complex of field piling static loading tests

#	Pile #	L, m	D, mm	Load, kN	S, mm
Static Compression Pile Loading Test					
1	SCPLT-1	20.50	600	1975	2.14
2	SCPLT-2	15.53	600	1310	1.48
3	SCPLT-3	21.85	600	1050	0.94
4	SCPLT-4	21.72	600	1050	1.08
Static Tension Pile Loading Test					
1	STPLT-1	20.50	600	600	0.41
2	STPLT-2	15.51	600	600	0.32
3	STPLT-3	21.71	600	360	0.16
4	STPLT-4	21.69	600	360	0.33
Static Lateral Pile Load Test					
1	SLPLT-1	15.51	600	200	6.19
2	SLPLT-2	20.50	600	200	7.27

Loading and unloading was carried out in the following sequence (for SLPLT): 0, 25, 50, 75, 100, 125, 150, 100, 50, 0, 25, 50, 100, 125, 150, 175, 200, 225, 250, 200, 150, 100, 50 and 0% of design. In the first cycle, the experimental pile was loaded to 150% of the design value (120 kN); during the second cycle, to 250% (200 kN) [12].

According to SLPLT result, the load-displacement diagrams were drawing (Figure 7).

7. CONCLUSIONS

Existing pile foundation standards practiced in Kazakhstan are out-of-date and are in urgent need for modernization. This paper presented very short descriptions of coming changes to the concept of Kazakhstan pile foundation design.

The results of the axial compression and tension loading tests performed in soft to firm or stiff clays demonstrated the suitability of CFA bored pile foundations. The results of the loading testing program confirmed that the CFA bored pile is a viable deep foundation option for construction Oil and Gas in remote areas West Kazakhstan and demonstrated their advantages.

The results of the full-scale load tests are also used to validate the theoretical model used for CFA bored pile design installed in soft and problematical soils of northwest of Kazakhstan.

The bearing capacity of CFA boring piles according to the results of shown table 5 amounted to be maximal load 1975 kN, settlement from 0.94 mm to 2.14 mm. These investigations are important for the understanding of the behavior of piles on problematical soil ground of Aksay, northwest of Kazakhstan.

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