Application of Static Compression Load Test of Joint Piles in Seaport "Prorva" in the Caspian Sea Coastal Area (Western Kazakhstan)

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ABSTRACT

2 segments precast concrete piles consist have been applied as foundations for "Cargo Transportation Route for of the north-eastern part of the Caspian Sea North Caspian Marine channel with berthing facilities Cargo Offloading Facility" (CaTRO, COF) the "Prorva" oilfield, Atyrau region in the Caspian Sea Coastal Area, Western Kazakhstan during November 2016 to July of 2017. This paper presents that seven characteristics engineering-geological elements (units) are identified based on the geological setting and the borehole logs. Testing of soils by piles was submitted by engineers of the LLP "KGS-Astana". The main purpose of this paper is to present many aspects of foundation construction in low temperature condition and freezing soil in winter season, to analyze the bearing capacity and a settlement of low temperature -5℃, -10℃. Pile testing was carried out in winter, when local climate and soil condition make is a 1 m. depth frozen soil make impact to the changing a ratio of ultimate bearing capacity and settlement. At the construction site of Seaport "Prorva" the static compression load test method was applied. In practice, SCLT is one of the widely used methods for analyzing of pile bearing capacity. This paper presents the result of the analysis of 2 joint concrete piles of number (d/36), (k/3). SCLT testing was holding on 2 cycles.

Key words: *site, pile, SLT, bearing capacity, frost heavy*

1. Introduction

1.1. Location of Seaport "Prorva"

The Caspian Sea is the largest lake on the Earth located at the junction of Europe and Asia. The water is subject to fluctuations; according to the 2009 data, it is 27.16 m below the sea level. The area of the Caspian Sea is currently about 371,000 km², the maximum depth is 1025 m. The Caspian Sea is located at the junction of the two parts of the Eurasian continent - Europe and Asia. length of the Caspian Sea from north to south is about 1200 kilometers. By the end of 1997 and by 2010, the sea level had stabilized at an absolute elevation of minus 27.00 m. The rise in the background sea level leads to a widespread long-term flooding of the Kazakhstan part of the Caspian lowland. Against the background of this flooding, short-term wind surges of sea water are even more actively affecting the low-lying coast, contributing to the flooding of even more significant areas, many higher than flooding from the rising sea level. Wind surges of sea water, flooding significant areas of the Kazakhstan coast, cause great material damage to the economy. Storm surges (sea) damage the fishery, throwing long-distance valuable species of fish, which, after the descent of the surging wave, perish in depressions in the relief of the coastal zone. In some parts of the coast, dams have already been constructed that cover large drainage valleys, along which storms and thawed waters flowed into the sea and surges were introduced on the coast. The average annual wind speed is 3-7 meters per second, in the wind rose the northern winds predominate. In the spring, autumn and winter month's winds increase, wind speed often reaches 20-25 meters per second most of the drainage occurs in the Northern Caspian, northern currents predominate. Storm surge is the rise or fall of water in the high seas, caused by strong winds - as a result of friction and shearing stress - on the surface of the sea. The coastal area is subject to the impact of wave waves caused by western winds and drifts caused by winds of the eastern direction (Geotechnical Interpretation Report, 2014).

1.2. Seaport "Prorva"

The project site for the construction of facilities for unloading cargo (CATRO) is located in Caspian Seaport "Prorva", which is in the coastal area. The main purpose of this paper is analyze bearing capacity and settlement joint concrete pile foundations SLT method in seasonally freezing soil. Conditions in local places include frozen soil in winter and flooding coastal areas of Caspian sea in spring, which changes ratio from bearing capacity and settlement of piles.

2. Static load test (SLT) on the site "Prorva"

2.1. Geological condition

The project area is located along the east coast of the North East Caspian Sea, both onshore and offshore, near the "Prorva" oil field, Western Kazakhstan. The project area is situated on the Northern Caspian Shelf. At present the North Caspian Sea has a limited water depth (maximum 5 to 8 m). The water level in the Caspian Sea depends on a balance between the inflow of river water and evaporation. This has resulted in large variations in sea level in the past. This explains the sequence and soil characteristics of the deposits (Zhussupbekov, 2016, Zhussupbekov, 2017).

2.2. Ground condition of constriction site

In 2012 a geotechnical survey was performed by Expro LLP (Expro) (Geotechnical Interpretation Report, 2014) consisting of 22 boreholes and 7 CPTs, and laboratory testing on samples taken in the boreholes. This geotechnical survey is received incomplete by WBCAS. All raw available data is used however.

The 2013 survey was set up to gather the required engineering data to establish a detailed design according to RoK standards.

The field work comprised geotechnical boreholes (BHG) and cone penetration tests (CPT). Field work according to British Standards was requested in the Scope of Work. The field testing campaign was executed between July and October 2013. The offshore campaign was carried out by CaspianGeoServices LLP (CGS) as subcontractor of Expro LLP (Expro) (Geotechnical Interpretation Report, 2014). The offshore survey was performed according to British Standards (in accordance with the Scope of Work). The onshore campaign was carried out by Geodang LLP (Geodang) as subcontractor of Expro LLP (Expro). The onshore survey was performed according to GOST/SNiP standards (GOST, 1994, GOST, 2001, GOST, 2012, MSP 5/01-101-2003, 2003).

The laboratory work comprised the execution of classification tests (water content, density, Atterberg limits, particle size distribution), strength tests (triaxial CU, triaxial CD, triaxial UU) and stiffness tests (odometer). The laboratory work was executed between November 2013 and March 2014.

Ten engineering-geological elements (units) are identified based on the geological setting and the borehole logs. These elements are ordered top-down, which means that unit EGE-1 is in principal in the top of the soil column, EGE-11 at the bottom of the soil column, and units EGE-2 to EGE-10 are situated in between these layers.

The geotechnical parameters are derived mainly from the laboratory testing on undisturbed samples taken in the boreholes using statistical analysis of test results in Table 1. For some layers or some parameters insufficient tests of good quality are available for statistical analysis. The process of derivation of geotechnical parameters is discussed for different clusters of geotechnical parameters, highlighting the engineering choices made and attention points identified during the process.

Parameters for EGE-4, EGE-6, EGE-10 were not derived because these units are only very locally present and not considered in engineering calculations.

The laboratory test program consisted of the following tests: - Classification tests: unit weight, water content, Atterberg limits, sieving, specific density. - Strength tests: triaxial tests (UU, CU, CD). - Compressibility tests: odometer test.

The soil strength parameters used as input for drained geotechnical analysis are the effective angle of internal friction (ϕ') and cohesion (c'). The soil strength parameter for undrained geotechnical analysis is the undrained shear strength (su).

The laboratory test results for strength parameters, based on triaxial tests, give a very scattered output for the strength parameters for each of the soil layers. Although the presence of some scatter is normal and some samples might have been bad, this large scatter is mainly attributed to the poor quality of the strength tests in laboratory.

Pure statistical analysis of these results would yield unrealistic values for the strength parameters. Therefore the cautious estimates for the strength parameters are made and evaluated against the more accurate classification parameters (Atterberg limits, water content, unit weight) with the use of correlations.

The soil profile is assumed to be derived at the location of the COF (with a ground level of BD-27.5 m).

Table 1 shows the engineering and geological section on the sites of seaport "Prorva".

The project area is situated on the Northern Caspian Shelf.

The value of actual frost heave depends on soil type, moisture content and temperature. In this region, in winter period the depth of the frost soil is average 1.0 m.

Table 2 shows thickness of snow covered on construction site "Prorva" in winter time (Geothechnical Interpretation Report, 2014).

Frozen soils behavior depends on temperature, rate of loading, etc (Phukan, 1991).

Table 1. Engineering-geological elements

Soil type	*C*	*φ*	$\gamma_{natural}$	*Su*	$E_{oed};$
	kPa	deg	kN/m^3	kPa	kPa
EGE-1 Fill sand	0.7	29.4	19.4	25	2.8
(EGE-2) Silt	0.7	29.4	19.3	15	2.750
(EGE-3) Sand	2.7	31.5	19	-	30
(EGE-7) Clay	20.8	24.7	19.1	80	2
(EGE-8) Sand	2.4	31.8	20	-	40
(EGE-9) Clay	22.7	23.8	20.6	150	4
(EGE-10) Clay	25	24.7	20.2	150	2

E_{oed} – Elastic unloading/reloading [kPa];
S_u – undrained shear strength [kPa].

Table 2. Thickness of snow cover on site

Thickness of snow cover			
The average date a snow cover	Average height in winter, cm	Maximum height in winter, cm	Minimum height in winter, cm
25/XI-10/III	13	26	3

The engineers of foundations must know changing physical and mechanical properties in freezing soil (Alexandar S. Vesic, 1977, Dalmatov, 2002, Dalmatov, 1988, Karlov, 2007, Nevzorov, 2000, Sarsembayeva, 2015, Shakhmov, 2013, Shakhmov, 2014, Tleulenova, 2018, Tsytovich, 1973). Taking into account the seasonal freezing of the soil and the frost heaving of the soil and the rising of the water level in the spring in the Caspian Sea (West Kazakhstan), the design consist is concrete joint pile foundations and around the perimeter of the sheet piles on the site.

The upper part of the active layer thaws in summer and refreezes winter (Shamsher, 1990).

2.3. Static compression load tests

Static load test should be carried out for driving piles after “rest”. For static compression load test (SCLT) the need next equipment: hydraulic jack DG 500, G 250 – 200-205 ton.

In **Fig. 1** illustrates 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 in 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 clamp to screw piles BAU 114*4*2000 drilled in soil with depth 1.5 m. (Zhussupbekov, 2017).

Fig. 2 shows SCLT 2 cycles loading and reloading pile foundations d/36 and k/3 in winter and spring times.

At the construction site, the sea port "Prorva", the static compression load test **(**SCLT) method. Method SCLT, which is a field test method was applied. In practice, Method SCLT is one of the widely used methods to analyze pile bearing capacity (Das Braja, 1984, Davisson, 1972, Eun Chul Shin, 2018). In paper analyze 2 joint concrete piles d/36, k/3. In SCLT testing, the test load on the pile is for hold on 2 cycles. Loading and unloading was carried out in the following sequence: 0, 30, 60, 90, 125, 90, 60, 30, 0, 170, 210, 250, 210, 170, 125, 80, 40 and 0% of design. In the first cycle, the experimental pile was loaded to 100% of the design value is 1311 kN; the second cycle is 1639 kN.

Table 3. Specification of piles d/36, k/3

Description	*material*	*L*	*b*	A_p
		m	m	m^2
No. d/36, k/3	concrete	27.5	0.4	11

This test presented piles behavior in real climatic conditions.

Investigations carried out for pile fields.

Fig. 1 Vertical static pile test using of SCLT method in seasonally freezing soil ground

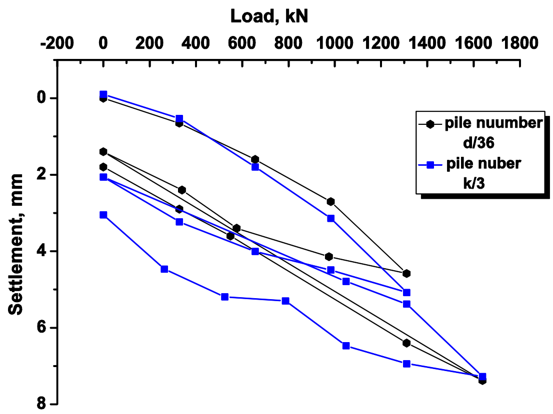

Fig. 2 Bearing capacity of piles number d/36, k/3

3. Press-in piling

3.1. Layout on construction site

This working plan (WP) has been developed for the production of driving operations of precast concrete piles consists of joint segments are the segment 1 length 16 m, segment 2 length 11.5 m, the total length 27.5 m, the reinforcement diameter of 8 mm (16 pcs) with across section 400x400 mm. Table 3 illustrated specification of piles d/36, k/3. Tested piles were drove by driving machine JUNTTAN PM25 (Zhussupbekov, Lukpanov and Omarov, 2016, Zhussupbekov and Omarov, 2016, Zhussupbekov, Omarov, Moldazhanova, Tulebekova, Borgekova, Tleulenova, 2017, Zhussupbekov, Omarov, Yergen, Borgekova, Tleuenova, 2017, Zhussupbekov, Shakhmov, Tleulenova, 2017, Zhussupbekov, Shakhmov, Lukpanov, Tleulenova, Kudryavtsev, 2017, Zhussupbekov, Shin, Shakhmov, Tleulenova, 2018)

3.2. Results of estimation analysis of bearing capacity

Table 4 shows the results of SCLT test. The total settlement of the pile foundation d/36 in time the first cycle was 4.4 mm, pile k/3 in time the first cycle was 5.2 mm. During the second cyclic settlement, the total settlement was for pile d/36 is 7 mm, for pile k/3 is 7.8 mm.

Table 4. Results of static test

Type of test	SF	Bearing capacity	Allowable bearing capacity	%
SCLT (piled/36) winter time	1.2	1639	1365	100
SCLT (pile k/3) spring time	1.2	1630	1358	99.4

3.3. Productivity on construction site "Prorva"

The whole project Seaport "Prorva" undertaken from November, 2016 till July, 2017. Piling machines used 2 units. About 1000 piles installed.

4. Conclusion

A construction for pile foundations is presented whereby two same pile types which been used in different frozen and unfrozen soil conditions.

There were 2 piles d/36, k/3 carried out test method of SCLTs, results of data bearing capacity d/36 pile foundation consist is 1639 kN, in frozen soils achieved 15 by loads and unloads, temperature -10(℃). In seasonally freezing soil k/3 pile bearing capacity consist is 1630 kN reached by 17 loads and unloads.

Frost heaving swelling is about 10 cm in Atyrau region site "Prorva". Comparison of the results of the settlement values of foundations on the construction site "Prorva" in the seasonally freezing soils showed that the value is 0.6% and the depth of ground freezing does not significantly impact the bearing capacity of the piles.

In Kazakhstan concrete, precast, reinforced piles are used in cold regions. These type foundations are stable and strong bases.

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References

Alexandar S. Vesic. 1977. Bearing capacity of shallow foundations, Design of pile foundations, pp. 121-129, Washington.

Dalmatov B. 2002. Soil ground and Foundations. pp. 255-272, Moscow, Russia.

Dalmatov B. 1988. Soil ground and Foundations. Moscow, pp. 260-270.

Das Braja M. 1984. Principles of Foundation Engineering. 2nd ed PWS Publishing Company. 20 Park Plaza, pp. 360-380.

Das Braja M. Soil Mechanics Laboratory Manual, Second Edition, Department of Civil Engineering. The University of Texas at EI Paso. Engineering Press, Inc. San Jose, pp. 41-59, California.

Davisson, M. T. 1972. High capacity piles. Proceedings of Lecture Series on Innovations in Foundation Construction, American Society of Civil Engineers, ASCE, Illinois Section, pp. 81-112, Chicago.

Eun Chul Shin, K. Park, A. Zhussupbekov, G. Tleulenova, Zh. Shakhmov. 2018. Application of Static Load Tests of Model Piles in Seasonally Freezing Soils in Kazakhstan. The 7th Technical Conference in Eastern Asia on Geo-Natural Disasters, pp. 53-54, Chengdu, China.

Geotechnical Interpretation Report. 2014. WBCAS 134-3.TN.028.F01.en Cargo Aktau.

GOST 5686-94. 1994. Methods for field testing by piles. Gersevanov Research Institute of Bases and Underground Structures (NIIOSP), pp 25-47. Moscow, Russia.

GOST 19912-2001. 2001. Soils. Field test methods by static and dynamic sounding. Gersevanov Research Institute of Bases and Underground Structures (NIIOSP), pp. 17-25, Moscow, Russia.

GOST 25358-2012. 2013. Soils. Field temperature determination method, pp. 3-10, Moscow, Russia.

Karlov V.D. 2007. Soil-based and Foundations on season freezing and swelling soil ground, pp. 135-170, Saint-Petersburg, Russia.

MSP 5/01-101-2003. 2003. Design and installation of pile foundation. Astana, Kazakhstan, pp. 4-8.

Nevzorov A.L. 2000. Foundations on seasonally frozen ground, pp 30-46, Moscow.

Phukan Arvind. 1991. Foundations in cold regions. Van Nostrand Reinhold, pp. 735-749, New York.

Sarsembayeva A. and Collins Ph. 2015. A modified Freeze-Thaw Laboratory Test for Pavement Sub Soil Affected by De-icing Chemicals. Engineering Geology for Society and Territory – Volume 6, Springer International Publishing Switzerland, pp. 243-243.

Shamsher Prakash, Hari D. Sharma. 1990. Pile foundations in engineering practice. John Wiley & Sons, Inc. pp. 589-605.

Shakhmov Zh. 2013. Influence of the freezing to soil ground of foundation, PhD Thesis, pp. 25-51, Astana, Kazakhstan.

Shakhmov Zh. 2014. Assessment of the degree frost heaving soil ground by different methods, International Scientific Conference of Young Scientists, pp. 4436-4443, Astana, Kazakhstan.

Standard Test Methods for Deep Foundations Under Static Axial Compressive Load D1143/D1143M – 07´1. ASTM, 2007.

SNiP RK 5.01-03-2002. 2002. Pile foundation, pp. 12-45. Astana.

SNiP RK 5.01-01-2002. 2002. Soil of basement and foundations. pp. 15-32.

SNIP RK 2.04-01-2010. 2011. Construction Climatology, pp. 6-17, Almaty.

SNIP RK 5.01-03-2002. 2002. Pile foundations, Committee for Construction of the Ministry of Industry and Trade of RK, pp. 25-84, Kazakhstan.

Tleulenova G.T., 2018. Application TRRL method of frozen soil ground. The XIII International Scientific Conference for Students and Young Scientists. Science and Education – 2018, pp. 6249-6253, Astana, Kazakhstan.

Tsytovich N. 1973. Mechanics of Frozen soil ground, pp. 125-148, Moscow.

Zhussupbekov A.Zh. and Omarov A.R. 2016. Geotechnical and construction considerations of pile foundations in problematical soils. Proceedings of the 8th Asian Young Geotechnical Engineers Conference, 8th AYGEC. pp. 27-32, Astana, Kazakhstan.

Zhussupbekov A, Omarov A, Moldazhanova A, Tulebekova A, Borgekova K, Tleulenova G. 2017. Investigations of the interaction of joint piles with problematical soil ground in Kazakhstan. Proceedings of Seventh International conference – GEOMATE 2017, pp. 383-388, TSU MEI, Japan.

Zhussupbekov A.Zh., Omarov A., Yergen A., Borgekova K., Tleuenova G. 2017. Piling Designing, Installation and Testing on Problematical Soil Ground of Kazakhstan. Proceedings of the 50th Anniversary Symposium of the Southeast Asian Geotechnical Society, pp. 77-80, Bangkok, Thailand.

Zhussupbekov A., Shakhmov Zh., Tleulenova G. 2017. Geotechnical problems on freezing ground soil and experimental investigations in Kazakhstan. Science in cold and arid regions. Volume 9, Issue 3, June, pp. 331-334.

Zhussupbekov A., Shakhmov Zh., Lukpanov R., Tleulenova G., Kudryavtsev S. 2017. Frost depth monitoring of pavement and evaluation of frost susceptibility at soil ground of Kazakhstan. ICSMGE 2017-19th International Conference on Soil Mechanics and Geotechnical Engineering, pp. 1455-1458.

Zhussupbekov A., Shin E. Ch., Shakhmov Zh., Tleulenova G. 2018. Estimation of the bearing capacity of pile foundations in seasonally freezing soil ground. Proceedings of the Second Geo-Institute-Kazakhstan Geotechnical Society Joint Workshop, pp. 65- 68, Orlando, New York.