XV Danube - European Conference on Geotechnical Engineering (DECGE 2014)
H. Brandl & D. Adam (eds.)
9-11 September 2014, Vienna, Austria
Paper No. 276

Research into time effect influence on pile bearing capacity

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Abstract. The paper presents the calculation of the bearing capacity of piles on the results of the cone penetration in soft water-saturated clayey soils considering the time factor. Comparison of this calculation with the pile load test is carried out.

Keywords: bearing capacity of piles, the time factor, soft water-saturated clayey soils, cone penetration test, pile load test.

1 INTRODUCTION

Full-scale testing of piles in weak water-saturated clay soils carries with it considerable financial losses connected with test duration and work content. Thereby, there arises a need for a reliable evaluation of the bearing capacity of piles based on the results of express methods, static probing (CPT) being one of the most common ones.

A great number of scientists, such as M.Yu. Abelev, A.A. Bartholomey, N.M. Bolshakov, N.M. Gersevanov, V.N. Golubkov, B.I. Dalmatov, A.A. Luga, G.F. Novozhilov, N.A. Tsytovich and many others were engaged in pile foundation research throughout the 20th century. It was established that the bearing capacity of a pile, driven into clay soil, increases with time. However, in spite of numerous studies carried out and developed methods of pile bearing capacity calculation taking into account time factor, it must be admitted that this factor has not been reflected in current normative documents, which regulate pile foundation design [1].

In this paper the authors made a comparison of pile bearing capacity determined by full-scale tests with the design values determined by the method of static probing taking into account time factor.

2 DESCRIPTION OF THE BUILDING OBJECT

A complex of concrete panel apartment houses of standardized model 97-N5.1 is being constructed in the suburbs of the city of Perm (Russia). These houses have pile combined foundations, namely, the foundations under internal walls are without framework with prefabricated reinforced concrete heads , the foundations under external walls are strip, single-row, with cast-in-situ reinforced concrete framework. C80.30-6.1 grade piles of 1.011.1-10 batch, output 1 are used as pile foundation elements under the exterior walls of a building and C100.30-6.1 grade piles are used under the internal axis, respectively. Design load on a pile is equal to N = 250 kN [2].

3 GEOTECHNICAL CONDITIONS.

Geologically, the construction site, within the depths examined (up to 14.0 m), is represented by alluvial deposits of the contemporary section of the quaternary system (aQIV) (Figure1).

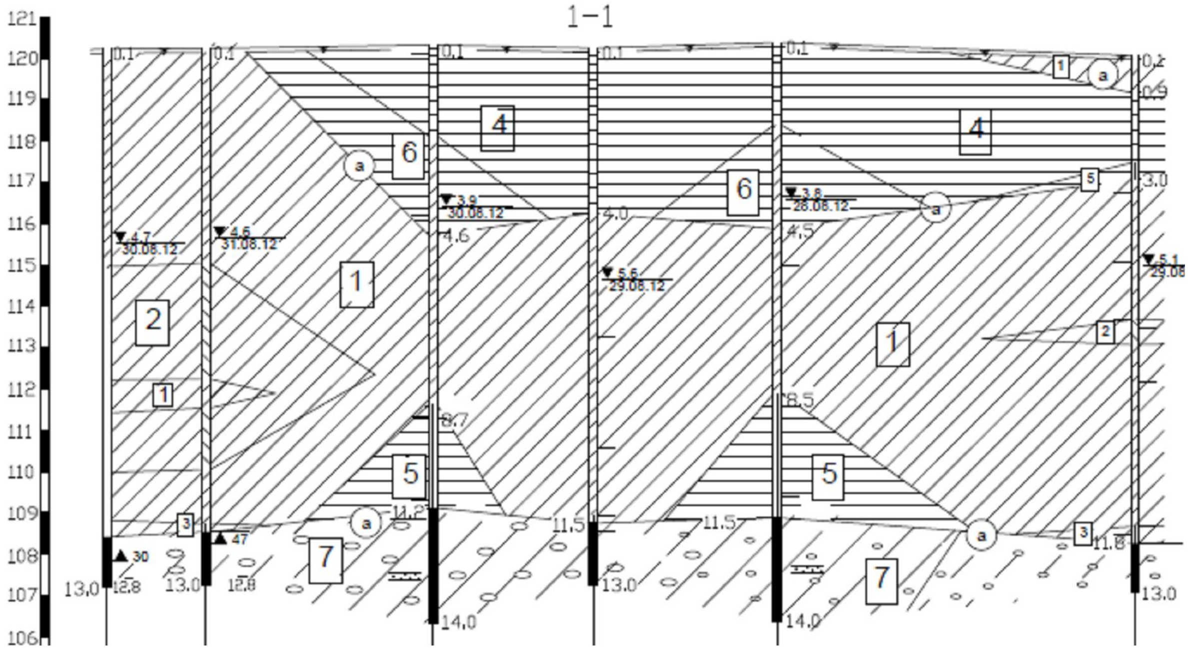

Figure 1. Engineering- geological profile of the construction site

A soil-vegetable layer of up to 0.1 m thick from the surface occurs everywhere. There are 7 geotechnical elements on the construction site:
GTE-1. Light silt loam, hard silt loam, soft plastic and stiff plastic loam (rarely) (aQIV);
GTE-2. Light silt loam, hard silt loam, very soft loam (aQIV);
GTE-3. Gravel, light silt loam, hard silt loam, stiff plastic loam (aQIV);
GTE-4. Light silt clay, bluestone and semisolid clay (aQIV);
GTE-5. Light silt, stiff plastic clay (aQIV);
GTE-6. Light silt, soft plastic clay (aQIV);
GTE-7. Gravel , pebble soil (aQIV).
At the time of the survey (August 2012) groundwater was found everywhere, in loams and clays (within the studied depths up to 14.0 m). A steady groundwater level was recorded at a depth of 3.8 – 5.6 m [2].

4 METHODS OF FIELD RESEARCH

The scheme of field test sites is presented in Figure 2.

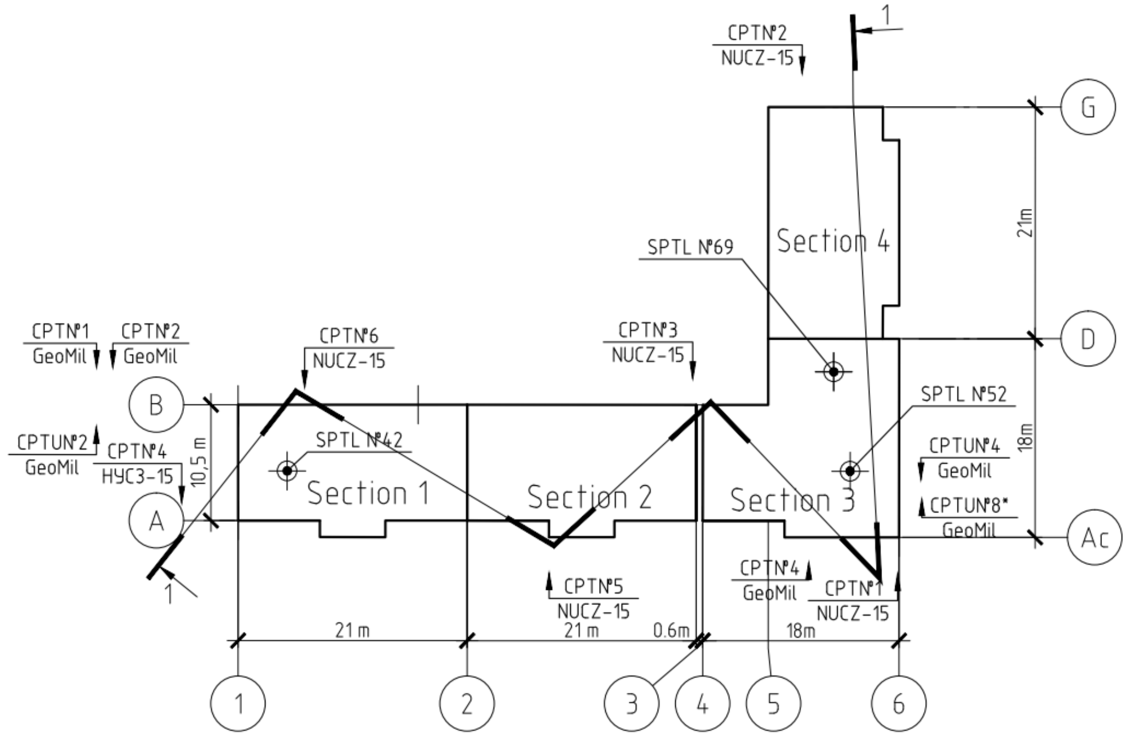

Figure 2. Scheme of pile test sites by means of static pile loading test (SPLT) and cone penetration test (CPT)

5 CONE PENETRATION TEST

It was carried out in accordance with GOST (State Standard) 19912 [3].
In the course of engineering-geological surveys (August 2012) cone penetration test of soils was performed with the help of plant NUCZ -15 of C-979 type using a mechanical system of probe jacking. A first-type probe was used. It had the following parameters: the diameter of the cone base was 35.7 mm, the angle at the vertex of the cone was 60 degrees, the area of the cone was 10 cm2, the outer diameter of the rods was 36 mm. The results of static probing are shown in Figure 3a and 3b.
In the period from August to September 2013, the laboratory of the Building Production and Geotechnics Department of PNRPU performed static probing of soils with the help of plant GeoMil LWC100 XS using a hydraulic system of probe jacking. Probing was carried out by a piezoelectric cone (CPTU) with a pore pressure sensor and a friction coupling (a 2-type-probe). The probe parameters were as follows: the diameter of the cone base was 35.7 mm, the angle at the vertex of the cone was 60 degrees, the area of the cone was 10 cm2, the area of the friction coupling was 150 cm2, the outer diameter of the rods was 36 mm, the length of the rods was 1 m. The results of static probing are given in Figure 3c and 3d.

6 PILE STATIC LOAD TESTS

In the period from April to June 2013 tests of piles were carried out in accordance with GOST 5686 [4]. A hydraulic jack latching each load increment on the manometer was used as a load device. Pile loading was carried out uniformly with load increments equal to 40.25 kN each (1/10 of 402.5 kN). There were three 10m long piles (C100.30 -6.1) tested , with the time interval of 9 days (pile № 42), 20 days (pile № 52) and 39 days (pile № 69) after their sinking. The bearing capacity of piles № 42, 52 and 69 was 402kN, 241kN and 350 kN, respectively [2].

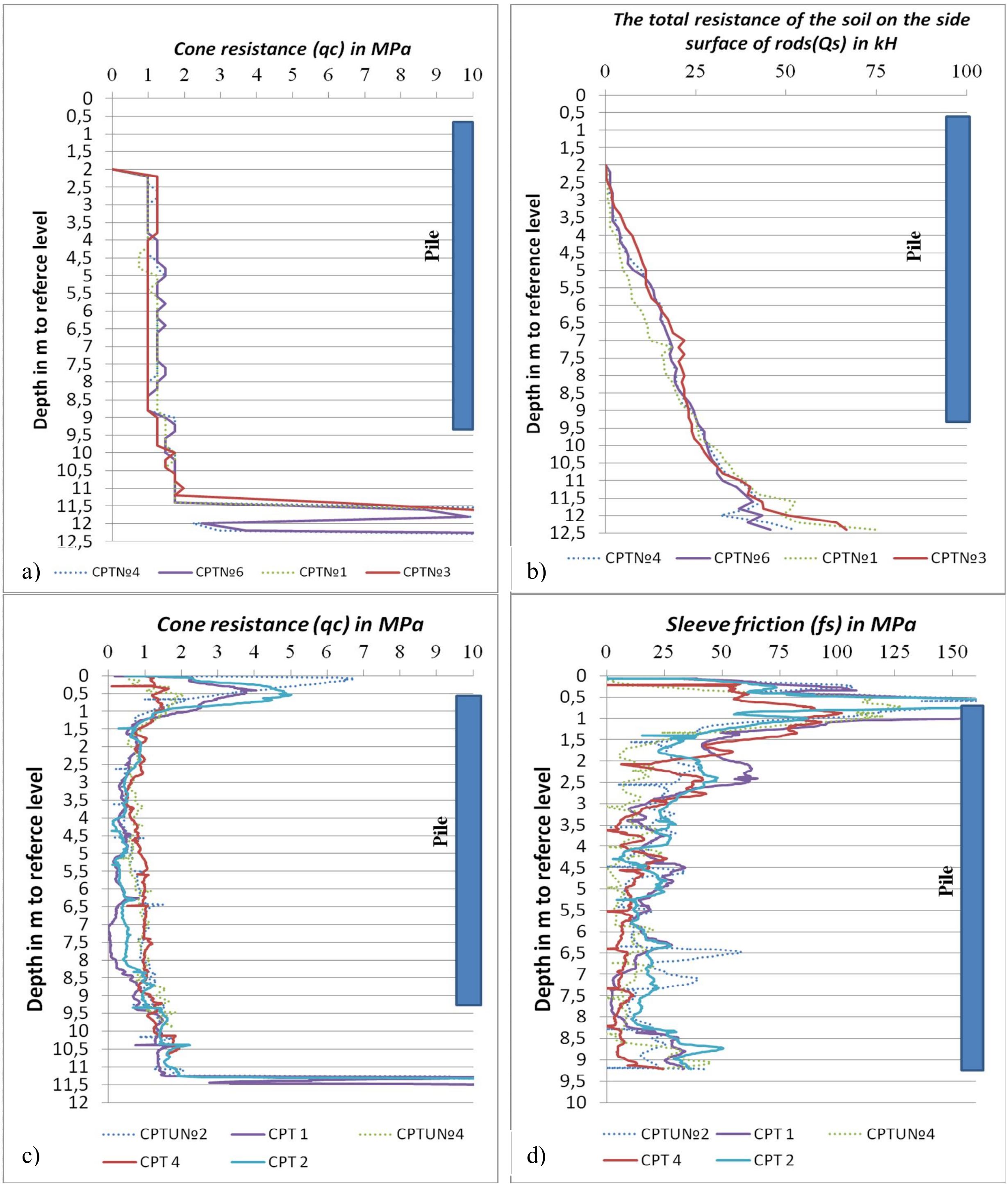

Figure 3. Results of Cone penetration test:a – resistance along the 1-type-probe cone; b – soil resistance along the sideface of the 1-type-probe; c – resistance along the 2-type-probe cone; d – soil resistance along the side face of the 2-type-probe.

7 PILE BEARING CAPACITY CALCULATION

Calculation of the pile bearing capacity on the static probing data was carried out in accordance with CP (Code of Practice) 24.13330.2011 [5]. Given the fact that the geotechnical conditions of the construction were presented by water-saturated clay soils with the degrees of saturation Sr = 0.841 – 1.026, the pile bearing capacity growth in time was predicted taking into account soil thixotropic strengthening and consolidation with respect to A.A.Bartolomey's methods [6, 7]. Calculations based on the geological engineering survey data were made. The results are shown in Table 1 and Table 2

Table 1. Pile bearing capacity determined by static probing

Test method	Cone penetration test №	Section	Pile bearing capacity (Fd) in кН				
			CP (Code of Practice) 24.13330. 2011[5]	0 day	10 day	20 day	40 day
NUCZ -15	CPT №1	3	480.41	464.49	488*	520*	598*
	CPT №3		448.57				
	CPT №4	1	483.36	481.14	505*	537*	616*
	CPT №6		478.92				
LWC1 00 XS	CPTU№ 4	3	263.04	276.83	297*	324*	383*
	CPT №4		290.62				
	CPTU№ 2	1	352.91	357.16	378*	407*	475*
	CPT №1		348.47				
	CPT №2		370.1				
*- pile bearing capacity was calculated by A.A. Bartholomey's methods [6,7]							

Table 2. Pile bearing capacity determined by static tests

Pile №	Section	Pile bearing capacity (Fd) in кН			
		0 day	10 day	20 day	40 day
42	1	381*	**402**	432*	502*
52	3	196*	215*	**241**	289*
69	3	248*	267*	294*	**350**
*- pile bearing capacity was calculated by A.A. Bartholomey's methods [6, 7]					

8 ANALYSIS OF THE OBTAINED RESULTS

Average the obtained results of calculations (Table 1, Table 2) and tabulate them in Table 3. For a visual comparison of the obtained pile bearing capacity values a pile bearing capacity histogram depending on the methods of calculation and time of 'rest' is submitted in Figure 4.

Table 3

Section	Test method	Pile bearing capacity (Fd) in кН				average deviation from SPLT
		0 day	10 day	20 day	40 day	
1	SPLT	381	402	432	502	x
	NUCZ-15	481	505	537	616	+25%
	LWC100XS	357	378	407	475	-7%
3.	SPLT (Average value of the pile 52 and 69)	222	241	267	319	x
	NUCZ-15	464	488	520	598	+98%
	LWC100XS	277	297	324	383	+22%
Average value of the sections 1 and3	SPLT	302	322	350	411	x
	NUCZ-15	473	497	529	607	+52%
	LWC100XS	317	338	366	429	+5%

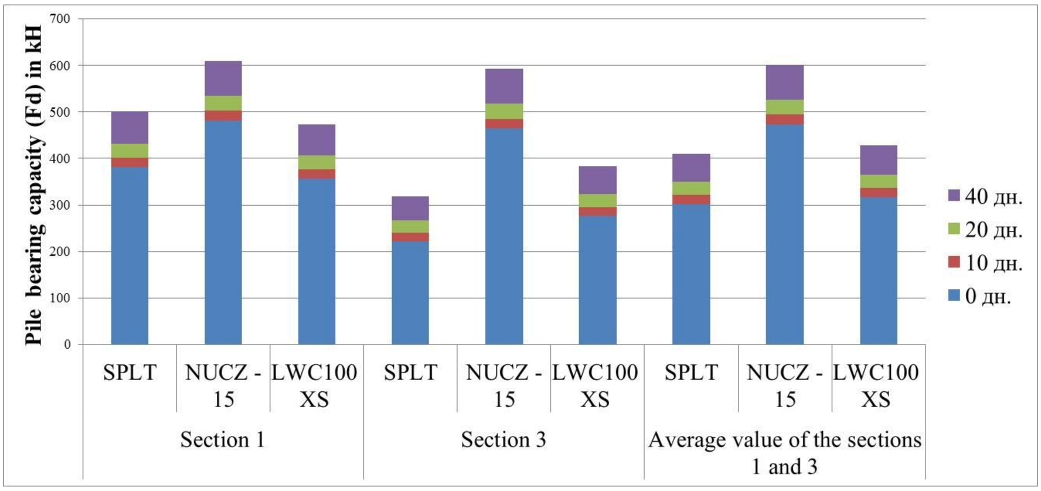

Figure 4. Histogram of pile bearing capacity changes with time

9 CONCLUSIONS

On the basis of the obtained results (Table 3, Figure 4) in respect to the soil conditions of the site, the following conclusions can be drawn:

1. The bearing capacity of piles determined by the static probing method with the use of a 1-type-probe brings about a 25-98 % overestimation of the bearing capacity of piles in comparison with the full-scale tests, greatly exceeding the value of the soil reliability coefficient ($\gamma k=1.25$) when determining the bearing capacity of piles by field test methods, according to CP 24.13330.2011 [5].
2. The bearing capacity of piles determined by the static probing method with the use of a 2-type-probe gives a 7-22 % divergence of the bearing capacity of piles in comparison with the full-scale tests, which allows us to predict the bearing capacity of piles in water-saturated clay soils close to real values.
3. The current method of pile bearing capacity calculation considering time factor is rather approximate. With the advent of modern static probing technologies, a piezoelectric cone with a pore pressure sensor (CPTU) in particular, it is possible to obtain more reliable soil parameter data and evaluate the pile bearing capacity in time. If the time factor in the design of pile foundations under similar geologic conditions is not considered, it will lead to a significant increase in the cost of construction, inefficient use of pile foundations and an increase in material capacity of geotechnical solutions.

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