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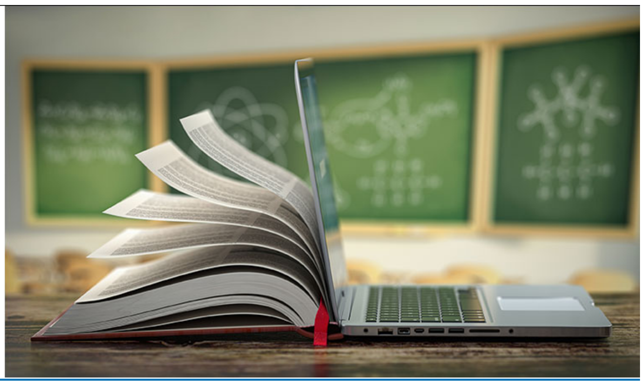

Forecast of the Development of Sediment Pile Foundations in Water-Saturated Clay Soils

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Abstract. The article presents the methodology and the main results of experimental studies of the laws governing the development of single-pile sediment in time on models under short-term and long-term exposure to loads. The obtained data are compared with the results of observations of precipitation of natural foundations. Indicates the direction of further research on the development of methods for predicting the sediment pile foundations. Established the legitimacy of the design of pile foundations for the maximum allowable deformations in the conditions of water-saturated clay soils.

1. Introduction

Large volumes of capital construction in oil and gas areas of Western Siberia in conditions of weak clay water-saturated soils led to the widespread use of pile foundations. However, using of pile foundations in some cases is constrained by the lack of sufficient data which is characterizing the actual conditions of their work in weak water-saturated clay soils. Especially it is about the questions of the development of sediment pile foundations in time [1-5].

It is known that static tests of piles which are performed on the construction site don't give a complete picture of the pile sediments in the structure under long-term load. To determine the final value of precipitation it is necessary to take into account the time factor. Experimental studies of piles under long-term load and comparison of the final sediment which were obtained experimentally, with theoretical data will clarify the scheme and methods of calculation of pile foundations for deformation [6, 7].

2. Simulation of experiments

The studying of the regularities of the development of pile sediment over time was carried out on large-scale models (scale 1:5) in a soil tray with dimensions of 2,2x4,2m in plan and a depth of 2.5 m. The tray dimensions allowed to create a homogeneous soil mass for simultaneous testing of a series of piles up to 25 pieces. At the same time, under the provided conditions the influence of the tray walls on the stress-strain state of the piles was excluded, as well as their mutual influence in the course of experiments.

The method of filling the tray with soil provided the creation of an array with physical and mechanical properties close to natural (weak clay water-saturated soils). The tray was loaded with loam layers of 10 cm with layer-by-layer compaction and soil moisture. As a result, according to laboratory experiments, the array of soil with the following physical-mechanical characteristics:

specific weight of soil of 16.2 kN/m3, gravimetric moisture content 38.8 per cent; porosity of 51%; the consistency of 0.5; 1.0 degree of saturation; specific traction 15 kN/m^2, angle of internal friction, 38^0.

There were accepted models of piles with cross-section 6x6 cm in length 1.3 m, made of concrete grade 300. Piles are immersed in the ground by pressing with a special installation. The study of the development of pile sediment in time was carried out by testing a series of 8 models with double repeatability of each experiment.

The sequence of experiments is accepted as a following: pile No. 1 is tested according to the method GOST 5686-12 «Soils. Methods of field tests with piles» [8] with increasing load steps to the limit state of the soil (2.8 kN). This test established a General pattern of pile operation and a range of loads on the phases of water-saturated soil in the near-well space was revealed. The obtained data made it possible to specify the number of experiments and the magnitude of loads for testing piles under long-term force action. Short-term and long-term tests are performed on seven models: piles 2-8.

A load on the piles under static tests according to GOST 5686-2012 [8] was carried out with the help of a support frame and a DG-5 hydraulic jack. The force in the jack was measured by a dynamometer DOSM-3. Precipitation during the tests were recorded by deflectometer 6PAO-LISI. The load during static tests was increased after the onset of conditional stabilization of precipitation from the previous loading stage. For conditional stabilization according to GOST 5686-2012, a draft equal to 0.1 mm for two hours of observation was taken. The total duration of such a test with bringing the load to the limit state of the soil was 56 hours. According to the results of experiments conditionally stabilized sediment Δ= 0,1 x S_{ud}=8 mm corresponds to a load of 2.6 kN (here S_{ud} is the ultimate deformation for buildings and structures) [9,10].

For experiments to determine the final value of the single pile shrinkage, a facility was designed that allowed the static load of a certain value to be transferred to the pile model for a long time. The loading was carried out through a special table with reinforced concrete elements with a weight of 0.35 kN. Of the seven tested models, three piles were loaded with a load corresponding to the soil compaction phase (0.7; 1.4; 2.1 kN), two models in the shear phase (2.6; 2.9 kN) and two in the area of the carrying capacity bases with a load of 2.95 and 3.05 kN. During the experiments, the values of conditionally stabilized sediments were measured in accordance with the requirements of GOST 5686-2012 for static tests and full pile sediments from long-acting loads.

3. The results of testing

The results of static load testing of piles, as well as the results of observations of pile shrinkage in time are given in table 1.

Table 1. The results of laboratory observations of the shrinkage of piles in time

Pile number	Load on the piles, kN	Conditional stabilized shrinkage – Δ, mm	The whole shrinkage S, mm	£= Δ/S
2	0.70	0.45	0.95	0.48
3	1.40	1.32	2.04	0.65
4	2.10	1.83	3.00	0.61
5	2.60	9.35	17.30	0.54
6	2.90	15.33	32.80	0.47
7	2.95	18.10	42.53	0.42
8	3.05	25.77	-	-
				$£_{mean}$ = 0.50

According to the test results, series of piles on the long-acting load, the generalized dependence of the magnification of conditionally stabilized precipitation on the load of the close to the static test data of the model No. 1 according to GOST, as well as the dependence on the load of the total precipitation of the piles (figure 1).

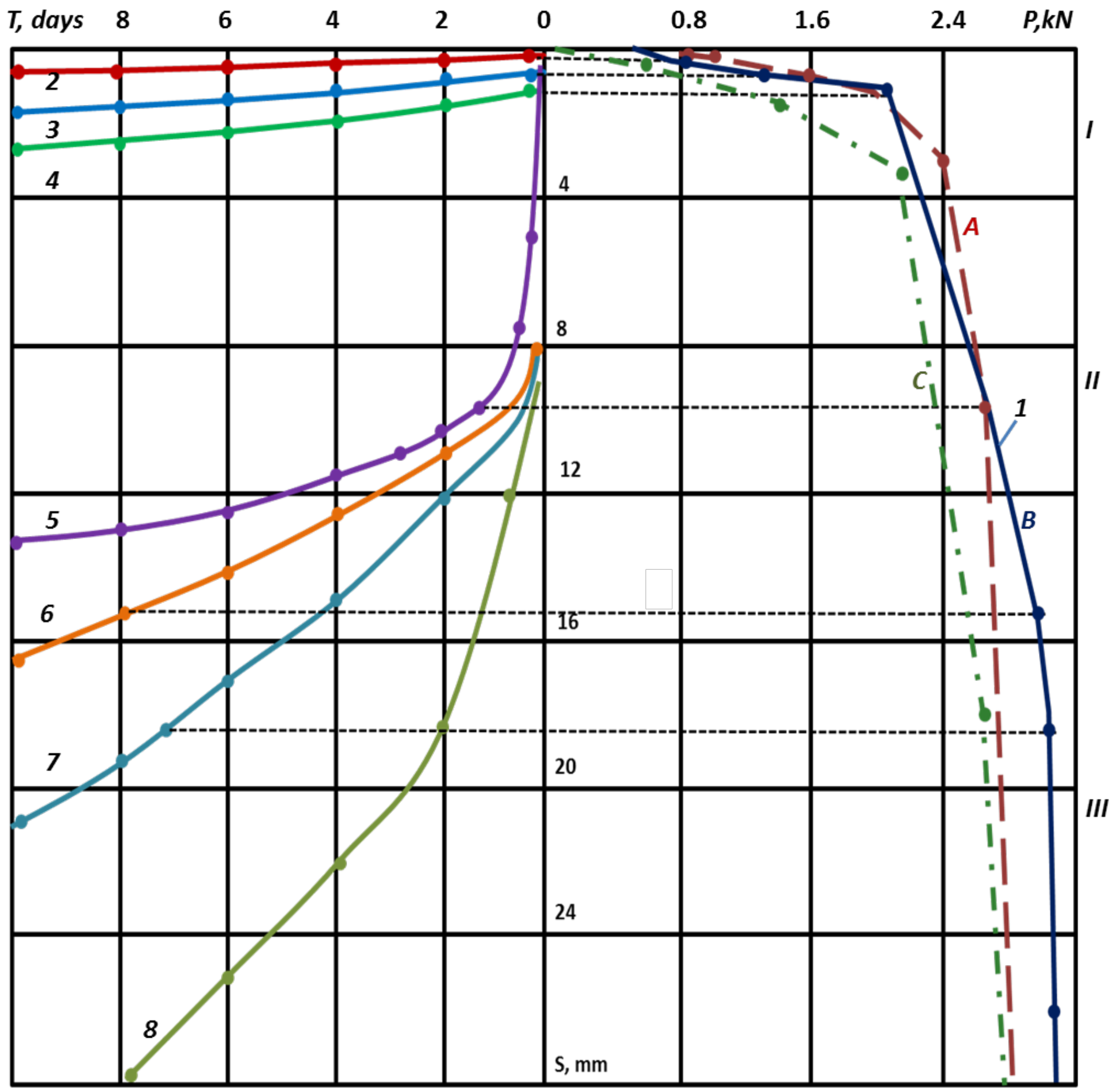

Figure 1. Test results, series of piles.

a, b - the development of deformation of piles in time; b - the dependence of the sediment on the load

(A - test pile No. 1 according to GOST5686-2012; B - generalized graph conditionally stable sediment piles No. 2-8; C - is also full of sediment); the I - phase of consolidation; II - the phase shifts; III - the phase of exhaustion of the bearing capacity of foundation piles (1-8 - numbers of experienced piles).

The obtained results indicate that the total sediment of a single pile is 1.55-2.35 times greater than the conditionally stabilized sediment (stabilization of 0.1 mm in two hours of observation). The average value of the transition coefficient from the conditionally stabilized precipitation to the total precipitation is 2.0.

It should be noted that the stabilization period of precipitation in the shear phase is much longer than in the compaction phase. Thus, the state of complete attenuation of precipitation in the compaction phase occurred after 30 days, and in the second phase of the sediment developed for several months. When the bearing capacity of the base was exhausted, it was not possible to obtain a conditionally stable state of the pile, since significant deformations developed with a small increment of the load. In this case, it is almost impossible to fix the value of the total precipitation and associate it with the concept of conditionally stable (figure 1).

Analysis of the results of laboratory experiments shows that the relationship between the total sediment and conditionally stabilized linear only in the compaction phase (figure 2).

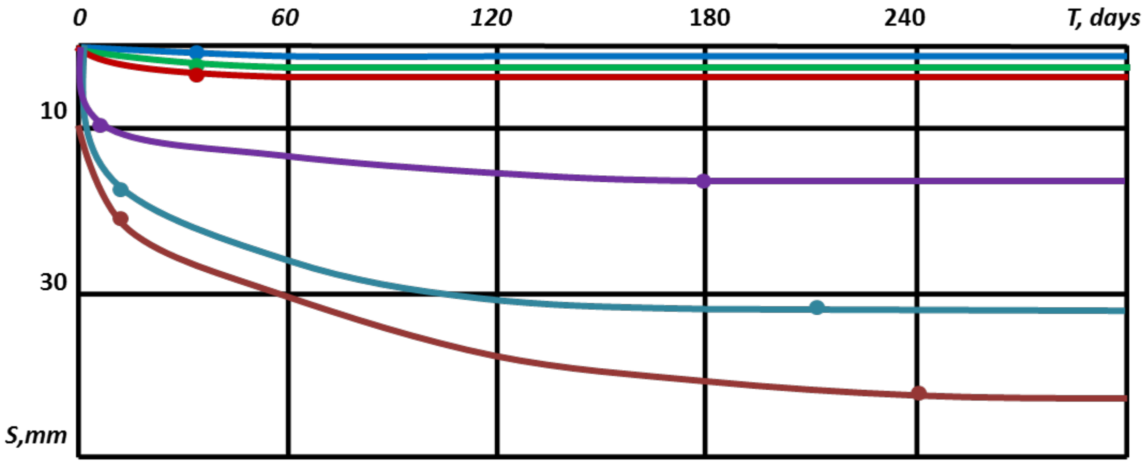

Figure 2. Dependence of the total sediment (S) and conditionally stabilized (Δ).

Transition rates the shrinkage of the pile is obtained in the test for possible sediment in the process of operation can be obtained by observing the development of precipitation of buildings and structures on piles.

Monitoring of the development of shrinkage of two five-storey residential buildings in Tyumen was carried out from the beginning of construction for two years. In engineering - geological respect, the construction site is heterogeneous, which is typical for the regions of the South of Western Siberia. The base is folded layers of sandy loam and loam. Piles in the Foundation composition are hanging/

When the foundations of the hanging piles bearing capacity per pile decreases. Theory and tests show that the total bearing capacity of the Foundation of hanging piles in clay soils is less than the product of the bearing capacity of one pile on their number in the Foundation. This is due to the mutual influence of piles by applying compaction zones around each pile in the foundation.[6-8, 12].

In the construction of foundations used piles with a cross section of 30x30 cm, hammering is made with a rod diesel hammer C-330 with a mass of the shock of 2.5 tons. The bearing capacity of the pile at the construction site is determined by the calculation method and the results of static tests of the piles. Calculation data and results of their comparison with static tests are given in table 2.

Building level is the intermediate point between the flat and a city. It is already not controlling the systems in a flat and still not controlling the overall energy flow of a city. IoT on a building scale is a data operator that gathers, analyses and transmits the information from every flat to suppliers.

Precipitation monitoring was carried out immediately after the completion of the construction and further within 24 months after the construction of the building. The final results of observations of precipitation over time are shown in table 3. Average stabilization of precipitation is accepted in accordance with GOST 5686-2012.

Table 2. The bearing capacity of the experienced piles according to the calculation and the results of static tests on the construction site of residential buildings in Tyumen

Pile number	Mark of pile	Immersion depth, m	Bearing capacity of pile			The percentage of the calculation is relatively static test, %
			On calculation F_d, кN	By results of static tests		
				Draft, mm	$F_{и,,}$kN	
1	C70.30	5.6	1712	20	1900	90.1
2	C70.30	4.7	2500	12	2000	125.0
3	C70.30	4.4	2224	13	2400	92.7
4	C70.30	4.1	2268	8.3	2400	94.5
5	C70.30	4.5	2230	8.1	2400	94.1
6	C70.30	5.4	1780	12	2600	68.5
7	C60.30	5.3	2469	30	2560	96/4
8	C60.30	5.0	2439	30	2550	95.6
9	C70.30	4.5	1660	30	2150	77.2

Table 3. Final results of the shrinkage of the pile foundations of residential buildings for 24 months of observations in the city of Tyumen

Object	Mark	Conditionally stabilized shrinkage, mm	The average probation stabilized shrinkage, mm	Full shrinkage of the building, mm (during 24 month), mm
1	M-1	8.2	9.8	27.0
	M-2	9.0		
	M-3	12.2		
2	M-4	12.0	13.3	32.8
	M-5	14.2		
	M-6	13.4		

The precipitation of pile foundations of these houses in time, as shown by observations, 4-5 times higher than the precipitation of single piles. This indicates that in addition to taking into account the time factor when calculating the value of the final precipitation, it is also necessary to assess the influence of the mutual arrangement of piles in the foundation [7].

4. Conclusion

The development of precipitation of natural foundations in time, according to the results of observations of precipitation, confirms the basic laws obtained by laboratory studies. The total draught of buildings for two years of observations in 2-3 times exceeded the size of the deformations recorded at the end of construction of houses. However, the total precipitation of buildings is insignificant in size and 3-4 times less than the maximum permissible.

Experimental studies of many authors [11, 12] show that the bearing capacity of pile foundations from hanging piles can be correctly estimated only on the basis of the maximum permissible sediment of buildings.

Based on the study of the actual pile sediment from the beginning of loading to complete stabilization and comparison of experimental and calculated data, methods for predicting sediment are developed.

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In addition, the legitimacy of the design of the foundations of residential buildings on the maximum permissible deformation in conditions of weak clay soils is established.

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