UDC 624.154
IRSTI 67.11.29
https://doi.org/10.51488/1680-080X/2021.3-13

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METHODOLOGY OF PILE SOIL TESTING

Annotation. *The construction of pile foundations is necessary if the active layers of the soil are weak, low-strength, and compressible, that is, they are unsuitable for the construction of shallow foundations on them without improving the soil properties. Piles transfer loads from the construction to the lower usually more compacted and strong soil layers. Pile foundations have found widespread use in the difficult soil conditions of Kazakhstan. In the article, the authors present the test results of the pile bearing capacity by statically pressing load. The conditions under which the tests were carried out, the used equipment, and the measuring instruments for obtaining data on the pile loading, its condition, and behavior in the soil mass are described. This technique is effective due to the possibility of testing in various engineering and geological conditions. The obtained test results are shown in the form of graphs-dependences of settlements on loads.*

Keywords: *piles, static test, bearing capacity, pressing load.*

Introduction. The reliability and safety of the constructions depend on the soil characteristics. There are two methods of soil survey: laboratory and field. The choice of the method for determining the indicators of soil properties during the engineering geology prospecting depends on the specified accuracy of this determination, on the engineering geology conditions of the construction design site primarily the composition and condition of the soils, on the structural design of the building mainly the structure of the foundations and the structure parts buried below the ground as well as the mode of its operation [1.2].

The soil survey under laboratory conditions allows identifying many physical and mechanical properties. However, the characteristics of soils determined under laboratory conditions on samples do not always fully reflect the soil properties in their natural state [3].

Field methods, on the other hand, make it possible to study the soil properties in large volumes and under conditions of their natural occurrence [3].

Determination of the soil bearing capacity by static tests refers to the field tests [4-8]. The pile bearing capacity determined by the static tests is the closest to the real pile bearing capacity in the structure and the differences detected in their values are sufficiently fully reflected by the correction coefficients presenting in the pile foundation design standards [9]. Dynamic tests are much more rapid, but not so reliable and applicable only to driven piles [10].

Materials and methods. Methodology for investigation of bearing capacity of piles. The survey of the soil bearing capacity by piles was carried out by GOST 5686-2020 [9]. When testing soils with the static pressing load the test pile loading is carried out evenly without impacts, by load increment the value of which is set by the test program, but not more than 1/10 of the maximum load specified in the program on the pile. When the lower ends of full-scale piles are buried in coarse-grained soils, gravel, and dense sands as well as clay soils of solid consistency, it is allowed to take the first three load increments equal to 1/5 of the maximum load.

For piles with a diameter of 800 mm or more separate tests are allowed on the full-scale pile lateral surface and under its lower end.

At each stage of loading the full-scale pile readings are taken from all devices for measuring deformations in the following sequence: zero reading – before loading the pile, the first reading – immediately after the load is applied, and then three successive readings with an interval of 30 minutes and then every hour until the conditional deformation stabilization (damping displacement).

When testing the soils with a reference pile or probe pile the readings at each load increment are taken in the following sequence: the first reading is taken immediately after the load is applied, then two readings are taken with an interval of 15 minutes, and thereafter with an interval of 30 minutes until the conditional deformation stabilization.

Discrepancies in the device readings shall not exceed the following values: 50% – with settlement less than 1 mm; 30% – with the settlement from 1 to 5mm; 20% – with settlement greater than 5 mm.

For the criterion of conditional deformation stabilization during the full-scale pile test the settlement of the pile is taken at a given incremental loading which does not exceed 0.1 mm over the last 60 minutes of observations if sandy soils or clay soils from hard to refractory consistency lie under the lower pile end or 2 hours of observations if clay soils from soft-plastic to fluid consistency lie under the lower pile end.

When testing pile bridge this criterion is taken as the rate of settlement not exceeding 0.1 mm for the last 30 minutes of observations – when the pile is supported on coarse-grained, sandy soils and clay soils of solid consistency or 60 minutes of observations – when the pile is supported on clay soils of semi-solid to refractory consistency.

When testing the reference pile or probe pile the criterion for conditional deformation stabilization is taken as the rate of pile settlement at a given incremental loading not exceeding 0.1 mm for the last: 15 minutes of observations if sandy and clay soils of solid consistency lie under the lower pile end; 30 minutes of observation if clay soils from a semi-hard to a stiff-plastic consistency lie under the lower pile end; 60 min of observation if clay soils from soft-plastic to fluid consistency lie under the lower pile end.

During the full-scale pile test, the load must be brought to a value at which the total pile settlement is at least 40 mm. At lower settlements, the duration of the pile holding under load at the last load increment even if the accepted conditional stabilization is achieved must be at least 5 hours unless another period of holding stabilization is specified in the test program.

When the lower full-scale pile ends are buried in coarse-grained, dense, sandy, and clay soils of a solid consistency the load must be brought to the value provided for in the test program, but not less than one and a half value of the pile bearing capacity determined by the calculation and not more than the design resistance of the pile shaft by the material.

In the control test of the pile during construction, the maximum load shall not exceed the design resistance of the pile shaft by the material.

In case of an unforeseen interruption in the tests, further pile loading and registration of the pile displacement are carried out by counting them from previously achieved values.

After testing the soil with a reference pile of type II to assess the ultimate soil resistance under the lower end of the pile its lower end is pressed by 20 mm and then (to assess the ultimate soil resistance on the lateral surface of the pile) the pile shaft is pressed or pulled out by 12 mm.

These tests are carried out without “rest” by the load increment and held for 15 minutes.

The time intervals between the end of the previous test and the beginning of the next test shall be indicated in the test log of the soil by the reference pile.

When using a reference pile of type III in addition to the total load on the pile at each load increment within the time specified in this document, readings are taken from a sensor registering the soil resistance under the lower end of the pile.

Pile unloading (full-scale, reference, or probe pile) is carried out after reaching the maximum load increment equal to twice the values of the incremental loading with a delay of each for at least 15 minutes.

The readings for measuring deformations are taken immediately after each unloading step and after 15 minutes of observations.

After complete unloading (to zero) observations of the elastic displacement of the pile shall be carried out for 30 minutes with sandy soils lying under the lower end of the pile and 60 minutes with clay soils with taking readings every 15 minutes.

After testing the reference or probe piles, they are removed from the soil. In this case, the pulling-out force is applied without jerks and along the pile axis.

Results and discussion. Tests. The object under study is the Big Almaty Ring Road "BAKAD" 2nd the Launch Complex, the bridge crossing over Boraldai River on PC 312 + 65.

At positive temperatures control static tests were carried out with pressing loads [9.11.12] of pile № 38 of support № 2 (see Figure 1) and pile № 45 of support № 1 (see Figure 2). Type of pile № 38 – driven prismatic C9-40T4, material – reinforced concrete, pile cross-section at the upper and lower ends – 40x40 cm, length – 9.00 m. Type of pile № 45 – driven prismatic C13-40, material - reinforced concrete, pile cross-section at the upper and lower ends - 40x40 cm, length – 13.00m.

Figure 1 – General view of the measuring system of pile № 38 prepared for work.

Figure 2 – General view of the measuring system of pile № 45 prepared for work.

Static pile load tests were carried out until the conditional stabilization of the pile settlement in accordance with the instructions of GOST 5686-2020 [9].

Power bench of inventory structures**,** jack DG200P250 and liquid pump were used as power and hydraulic equipment. Measuring and control devices: deflectometer 6PAO-0.01, deflectometer 6PAO-0.1, gauge tape 5 m, manometer WIKA.

The calculated value of the load applied to the pile head is determined by the structure design by the provisions of GOST 5686–2020 [9] and SP RK3.03-112 -2012 [11]. The load coefficient of safety for this test is defined – 1.5.

The planned pressing load was 104.0 for pile № 38 and 107 for pile № 45 (Table 1). Loading the tested piles was carried out evenly without impacts by incremental loading the value of which was no more than 1/10 of their estimated load-bearing capacity.

The force created by the jacks at the first load increment was 10.4 tf for № 38; each next load increment had an increase of 10.4 tf and for № 45 – 10.7 respectively.

Table 1 - The pile design load by the project data and the maximum pressing load during the test

Pile number	Design calculated load on the pile. – P_{calc}, t	Maximum pressing load on the tested pile. - P_{max}, t
38	for the project – 69.6	104.0
45	for the project – 71.0	107.0

At each pile load increment, readings were taken for all devices at 30 minutes intervals until fading the displacement (settlement) of the piles called conditional stabilization.

According to the project, for the conditional stabilization of the pile was taken the speed of its displacement (settlement) in the soil by GOST 5686-2020 [9] not more than 0.1 mm over the last 60 minutes of observations at this incremental loading.

The zero reading from the devices was taken before loading the pile.

The first reading was taken immediately after the application of the first load increment then the readings were taken sequentially every 30 minutes up to four times until the deformation (displacement fading) was stabilized at the first load increment.

For pile № 38 (support № 2):

The holding period of each stage from the first to the final under pressure loads was at least 120 minutes per stage.

At the sixth stage the holding period was 390 minutes.

The maximum displacement of the pile when averaging the indicators of control devices indicators 6PAO (P2, P1) when reaching the load 62.4 tf the pile was 41.715 mm (see Figure 3).

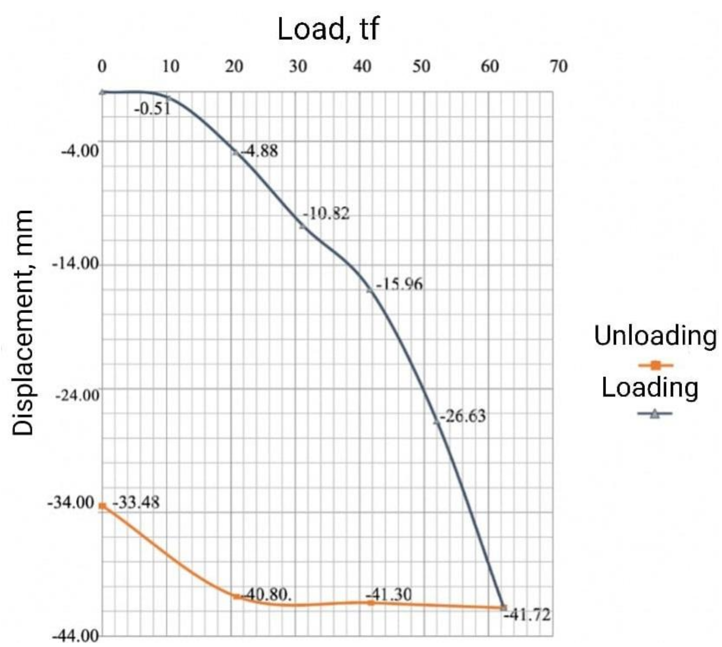

Figure 3 - The results of the total settlement of pile № 38 at all test stages (according to the average readings: Loading, Unloading – deflectometer 6PAO)

For pile № 45 (support № 1):

The holding period of each stage from the first to the ninth under pressure loads was at least 120 minutes per stage.

At the eighth stage, the holding period was 480 minutes.

The maximum displacement of the pile when averaging the indicators of control devices indicators 6PAO (P2, P1) when reaching the load 85.6 of the pile was 41.43 mm (see Figure 4).

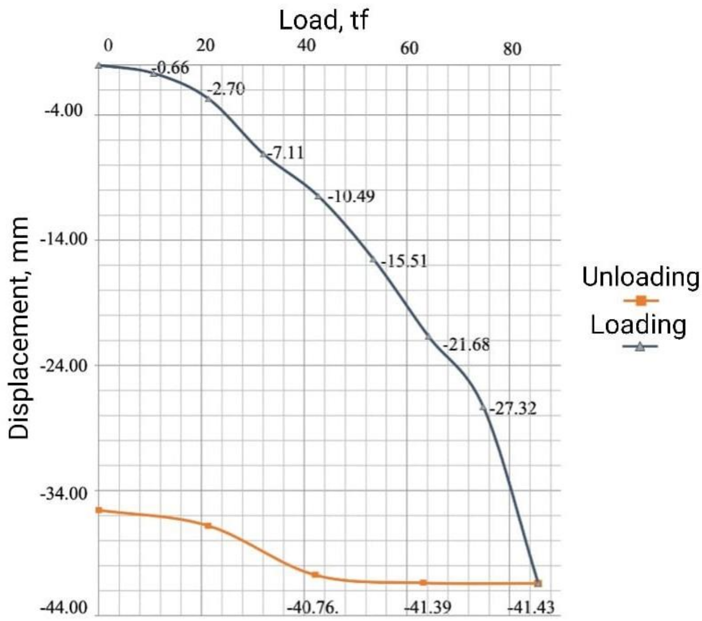

Figure 4 - The results of the total settlement of pile № 45 at all test stages (according to the average readings: Loading, Unloading – deflectometer 6PAO)

Results and discussion. Static tests of pile № 38 on support № 2 with pressing loads showed that at the sixth stage of the pressing load equal to 62.4 tf the deformation (settlement) of 41.715 mm was recorded. For pile № 45 on support № 1 at the eighth load increment equal to 85.6 tf the deformation is equal to 41.43 mm. However, according to the observation results, the settlement did not stabilize in both cases.

According to SP RK 5.01-103-2013 [12] the ultimate resistance of the pile F_u under pressing loads is taken the load (fifth stage) - 52.0 tf (№ 38), seventh stage (№45) - 74.9 tf. The test results showed that the load-bearing capacity of the tested piles on the soil is insufficient to accommodate the maximum pressing design load.

Conclusion. Static tests play an important role in the stage of the survey – is the choice of the most rational design solution of the piles, their number and placement in terms of the future structure, and at the construction stage (control tests) – the determination of the actual pile bearing capacity on the soil. A correctly selected program of static tests taking into account the actual nature of the work of the piles in the future building foundation makes it possible to identify the reserve of the soil bearing capacity. The obtained survey results prove that this method is the most reliable since for most weak, water-saturated, clay soils the dynamic method does not produce accurate results. Based on the results of the "reference" tests a decision is made on further measures – on the need to increase the length or number of piles.

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ТОПЫРАҚТЫ ҚАДАЛАРМЕН СЫНАУ ӘДІСТЕМЕСІ

Аңдатпа. *Егер топырақтың жоғарғы қабаттары әлсіз, беріктігі төмен және аса сығымды болса, яғни топырақтың қасиеттерін жақсартпай бұрын үстіне шағын іргетастарды орналастыру жарамсыз болып тұрса, онда қадалық іргетастарды орнату қажеттілігі пайда болады. Қадалар салмақты ғимараттан төменгі, әдеттегідей, аса тығызданған және беріктілігі жоғары топырақ қабаттарына береді. Қадалық іргетастар Қазақстанның күрделі топырақ жағдайында кең қолданыс тапты. Мақалада авторлар статикалық баттыру қысым түсіру арқылы қадалардың көтергіш қабілетін сынау нәтижелерін ұсынған. Сынақтар өткізілген жағдайлар, қолданылған жабдықтар, қаданың жүктелуі, оның топырақ сілеміндегі күйі мен құлқы туралы ақпараттарды алатын құрылғылар сипатталған.*

Түйін сөздер: *қадалар, статикалық сынақ, көтергіш қасиет, баттыру жүктемесі.*

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МЕТОДОЛОГИЯ ИСПЫТАНИЙ ГРУНТА СВАЯМИ

Аннотация. *Необходимость устройства свайных фундаментов возникает, если верхние слои грунтов являются слабыми, малопрочными и сильносжимаемыми, то есть они являются малопригодными для устройства на них фундаментов мелкого заложения без улучшения свойств грунтов. Сваи передают нагрузки от сооружения на нижние, как правило, более уплотненные и прочные слои грунта. Свайные фундаменты нашли широкое применение в сложных грунтовых условиях Казахстана. В статье авторами представлены результаты испытаний несущей способности свай путем статически вдавливающей нагрузкой. Описаны условия, в которых проводились испытания, используемое оборудование, измерительные приборы для получения данных о загружении сваи, ее состоянии и поведении в грунтовом массиве.*

Ключевые слова: *сваи, статическое испытание, несущая способность, вдавливающая нагрузка.*