Збірник наукових праць. Серія: Галузеве машинобудування, будівництво

Academic journal. Series: Industrial Machine Building, Civil Engineering

http://journals.pntu.edu.ua/znp

https://doi.org/10.26906/znp.201X.XX.XXXX

UDC 624.154

Work piles - columns with soil under constant influence of vertical and cyclically approximated horizontal loads

Barchukova Tetiana[1]*

[1] Odessa State Academy of Civil Engineering and Architecture https://orcid.org/0000-0002-1667-4179
*Corresponding author: *tanabapchycova@gmail.com*

The article describes an experimental study aimed at identifying common patterns of joint work of piles - columns with soil with vertical and cyclically applied horizontal loads. The study examines the deformation processes occurring in the soil. At any pressure value, soil deformations can be divided into two groups, which are restored (elastic) and residual. When the pressure is less than the structural strength, elastic deformations appear. With a pressure of greater structural strength, elastic and residual deformations appear. Elastic deformations appear throughout the depth, residual deformations develop in the depth of the deformation zone, where the stress exceeds the structural strength of the soil. After removing the load, the elastic deformation disappears, and the residual remains. The lower limit of the residual strain zone is at a depth, where the stresses from the load transmitted by the column of piles below its base are balanced by the structural strength of the soil.

Keywords: geological structure of the site, pile - columns, experimental study

Спільна робота палі-колони з ґрунтом основи при дії вертикального і циклічно прикладеного горизонтального навантажень

Барчукова Т.М.[1]*

[1] Одеська державна академія будівництва та архітектури
*Адреса для листування: *tanabapchycova@gmail.com*

Описано експериментальні дослідження, спрямовані на виявлення загальних закономірностей спільної роботи палі-колони з ґрунтом основи при постійно діючому вертикальному і циклічно прикладеному горизонтальному навантаженнях. Установлено, що при значенні тиску деформації ґрунту можуть бути розділені на дві групи: ті, що відновлюються (пружні), й залишкові. Доведено, що при напрузі, меншій ніж структурна міцність, виникають пружні деформації, при більшій – в основах спостерігаються два види деформації – пружні в межах усієї глибини зони і залишкові, що розвиваються в межах глибини зони деформації, де напруга перевищує структурну міцність ґрунту. Зазначено, що після зняття навантаження пружні деформації зникають, а залишкові залишаються. Нижня межа зони залишкових деформацій знаходиться на глибині, де напруги від навантаження, яке передається палею-колоною нижче її підошви, врівноважуються структурною міцністю ґрунту. Пружні деформації наростають по глибині за лінійним законом, при залишкових деформаціях залежність між деформаціями і напруженнями буде нелінійною. Визначено повне осідання і залишкову складову деформації, величини яких зі збільшенням горизонтального навантаження зростають. Установлено, що величинам пружної складової осідання, горизонтальних переміщень дорівнюють різниці між величинами повної та залишкової складових деформації. Виявлено, що під дією горизонтального навантаження паля-колона повертається в точці нульових переміщень – у результаті ґрунти перед навантаженою гранню колони ущільнюються, наслідком ущільнення є переміщення палі: її поворот у рівні денної поверхні в бік дії сил, а підошви – у зворотному напрямку.

Ключові слова: геологічна будова майданчика, паля-колона, експериментальне дослідження

Introduction. The determination of deformations occurring in soils is of great importance for the practice of designing foundations, since deformations of foundations are the factors that characterize the durability of structures.

Under the influence of loads in the soil mass, stresses arise and, as a result, their deformation develops in soils. The formation of tension in the soil column does not occur instantaneously under the influence of the load, but can develop for a rather long time. There are three phases of the stress state of the soil [1]:

Phase 1 – the phase of compaction, damped deformations, when the deformation speed tends to zero.

Phase 2 – phase shifts, the strain speed acquires a constant value, some local shifts occur at the edges of the foundation; soil carrying capacity is not exhausted yet.

Phase 3 – the bulging phase is a sharp increase in precipitation with a slight increase in the magnitude of the load, as well as the swelling of the soil to the sides and upwards.

O.N. Tsytovich considered in his works not three phases of the stressed state of soils arising under the basement foundations with a constant increase of load on the ground, but two: the phase of compaction and local shifts and the phase of development of significant shifts [2].

In the article the deformations that develop in the soil under the pile-column bottom, corresponding to the stress state arising in the first phase, the compaction phase are looked through.

The analysis of recent research and publications. A great contribution to the study of the processes of soils deformation arising in the foundations of the foundations made the works of the following scientists: Tugayenko Y.F., Marchenko M.V., Tkalicha A.P., Mosicheva I.I. [3, 4, 5]. In the workTugayenko Y.F. [3] summarizes the results of studies of the increase in deformation at the base of piles, foundations and pile foundations. The results of studies on the formation of a compaction zone during pile driving and the development of a deformation zone due to external loads are presented. According to the test results, the value of the settlement of the piles, its elastic and residual components were recorded, the facts of changes in the deformations in depth were presented, and their quantitative assessment was given.

The emphasizing of previously unsolved parts of the general problem to which the article is dedicated. In the above presented works, the deformation of soils arising under the action of vertical force is considered. In this article, the deformations that develop during the testing of the pile-soil system under the joint action of vertical and cyclically applied horizontal loads are studied.

The formulation of the problem. The purpose of the work is to identify the general patterns of joint work of the pile - columns with the foundation soil. The task of the study is to conduct a full-scale test of a pile-column with a foundation soil under the action of loads.

The main material and results. A short-pile column was tested on one of the construction sites. The structure of the site is characterized by the following engineering-geological elements: layer 1. Bulk grounds, represented by brown and dark brown loams with rubble, construction and household debris, with a capacity of 0.1 m; layer 2. Loams are dark brown, macroporous, with a capacity of 3.8 m (E = 18/7 MPa; p = 1.69 g / cm^3; pd = 1.43 g / cm^3; w = 0.18; φ = 230; s = 10 kPa); layer 3. Yellowish-brown, loess-like, macroporous loam, 4.0 m thick (E = 29 MPa; p = 2.03 g / cm^3; pd = 1.68 g / cm3; w = 0.21; φ = 260 ; c = 15 kPa). During the exploration ground waters were found at a depth of -6.3 m.

The geometric parameters of the tested pile: cross section 0.3 · 0.3 m, length - 5 m, depth of immersion in the ground – 3 m. The experimental pile is made with broadening. Broadening is an increase in the cross section of the underground part of the pile in the level of the surface. The cross-section of broadening – 1.0 · 0.8 m.

The installation method – a pile-column is driven into the ground with the help of a pile driver S-878 A based on the tractor T-100 MBGP, hammer C-330.

The test was carried out in full size under the action of vertical force and horizontal loads (Fig. 1), in the laboratory such studies are carried out using an elastomer [6].

The vertical load was created by placing the calibrated load on a special platform, which is mounted on a pile-column. Loading was carried out uniformly, one step at full size.

After stabilization of the precipitation from the vertical force, horizontal loads, which were created by a winch, attached to the anchor pile column, were applied. Horizontal loads were applied in steps, each step of the load was maintained until the horizontal displacements stabilized, after which full unloading was performed, then the next step of horizontal force was applied. The load in each cycle consisted of the sum of the previous and next steps, except for the first and second steps in which the horizontal forces are equal to Q = 17 kN.

For the conditional amount of stabilization in the study, it was assumed: increment speed: precipitation from a load of not more than 0.1 mm per day, horizontal displacements of 0.1 mm in the last two hours.

Horizontal forces were measured with a dynamometer with a scale division of 7.5 kg.

Measurements of the sediment from the loads were made using a depth gauge with a precision of 0.1 mm. The pile draft was determined by measuring the distance from the edges of a double-solo reference beam rigidly connected with the pile and supporting rods. The support rods were stained with concrete in the well to a depth of 1.0 m outside the zone of influence of the load on the base soil. The pile settlement was determined as the average of two measurements.

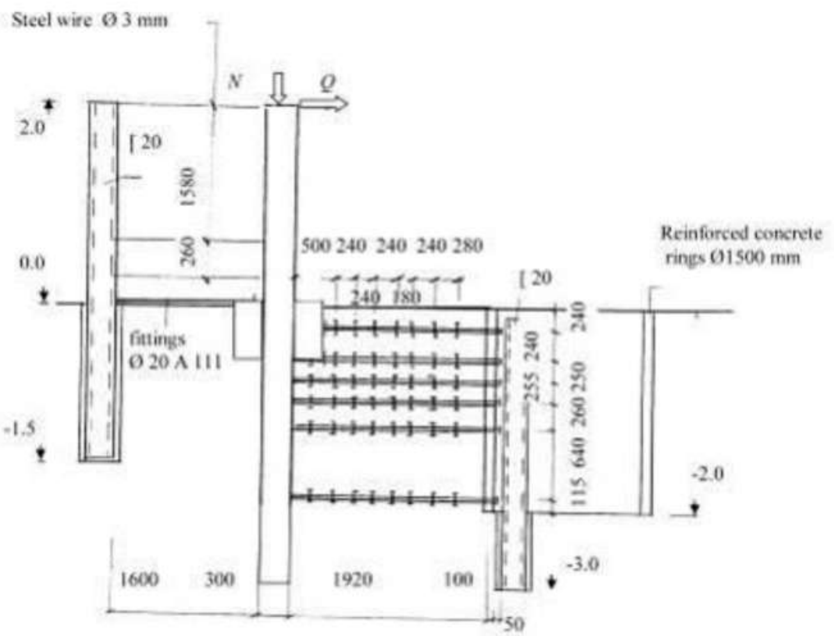

Figure 1 – The diagram of load application and installation of magnetic grades

Horizontal movements at the level of the day surface and along the height of the superfundum part were recorded using slider defibomers.

The horizontal displacements of the underground part of the pile were measured by the displacements of the tubes by the depth gauge from the reference system located in the pit, located at a distance of 2.0 m from the loaded face of the pile. Tubes were laid from a shur-fa with a vertical step 240 ... 640 mm Measurement accuracy of 0.1 mm.

The movement of the soil in front of the loaded face of the pile was measured by magnetic marks and a special device. Stamps were mounted in horizontal wells drilled from the hole in two rows: along the axis of the column with a vertical step of 240 ... 640 mm, to a depth of 2 m, horizontally 180 ... 280 mm and along the axis at a distance of 290 mm from the center columns. The movements of marks were recorded by the device with a reference accuracy of up to 0.01 mm relative to the reference system installed in the pit.

The results of the study. According to the experiment, a graph of precipitation versus permanent vertical and cyclically applied horizontal loads (Fig. 2), characterizing the dynamics of precipitation increase over time, was built. The graph shows the process of stabilization of precipitation, from each stage of the horizontal load in the process of experience and after its completion.

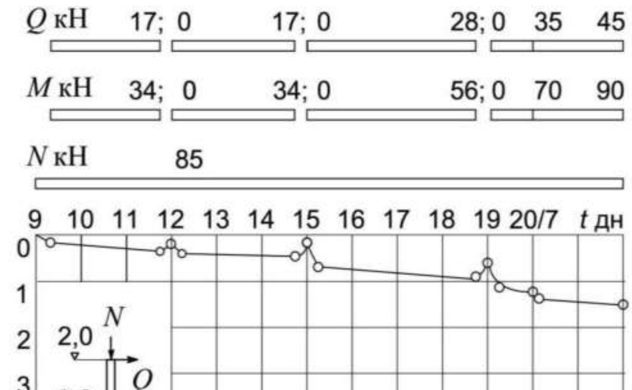

Figure 2 – The graph dependence of pile-column precipitation on the loads in time

If in the process of loading the soil, when some values are reached, unloading is performed, then it can be noted that, at any pressure value, the unloading does not cause a complete recovery of the soil deformation (Fig. 2). Consequently, at any pressure value, the deformations of the soil can be divided into two groups - regenerative (elastic) and residual.

At stress, less structural strength, elastic deformations occur, with greater, two types of deformation are observed in the bases - elastic within the entire depth of the zone and residual, developing within the depth of the deformation zone, where the stress exceeds the structural strength of the soil. After the removal of the load, the elastic deformations disappear, and the residual ones remain. The lower boundary of the zone of residual deformations is located at a depth, where the stresses from the load transmitted by the pile-column below its base are balanced by structural strength.

Elastic deformations are a consequence of the mutual repulsion forces between the atoms of the soil crystal lattice during their mechanical «approach»; the manifestation of the elastic properties of gases and liquids in the pores; the emergence of forces, «wedging» pressure in the soil [7, 8].

The residual deformations are the result of the manifestation of the plastic properties of the soil, namely: the destruction of individual structural bonds during deformation; the displacement of particles (crystals, grains, debris, etc.); the squeezing of water and gases from the pores; the gradual accumulation of microdefects in the structure of the soil, which cannot be restored themselves [7, 8].

Elastic deformations increase in depth, according to a linear law, that is, the equations and dependences of the theory of elasticity can be used to determine stress, based on a linear relationship between stresses and strains, with residual strains, the relationship between strains and stresses will be non-linear. Residual deformations determine the irreversible processes occurring in the foundations of the foundations.

As a result of the study, the total sediment and the residual component of deformation were determined, the magnitudes of which increase with increasing horizontal load. With an increase in the horizontal force by 1.6 times, with a constant vertical load, the residual strain is 4 times greater at Q = 28 kN than at Q = 17 kN (Fig. 2).

Under the action of a horizontal load, the pile rotates at the point of zero-left displacements. As a result, the soil in front of the loaded face of the column is compacted, the result of compaction is the movement of the pile, its rotation at the level of the day surface towards the action of forces, and the soles in the opposite direction.

The rotation reduces the contact area of the side surface of the pile with the ground, reducing the amount of resistance of the pile on the side surface. The reduction of friction forces causes an additional draft of the pile, the value of which increases with increasing horizontal forces.

Figure 3 shows a graph of the horizontal displacement of a pile-column from the loads in time. The graph shows the process of stabilization of horizontal displacements, from each stage of the horizontal load in the process of experience.

The magnitude of the elastic component of the precipitation, the horizontal displacements is equal to the difference between the values of the total and residual components of the deformation.

Under the action of loads Q = 45 kN; M = 90 kN m; the elastic component is equal to 27% of the total precipitation and 29% of the total horizontal displacement of the soil.

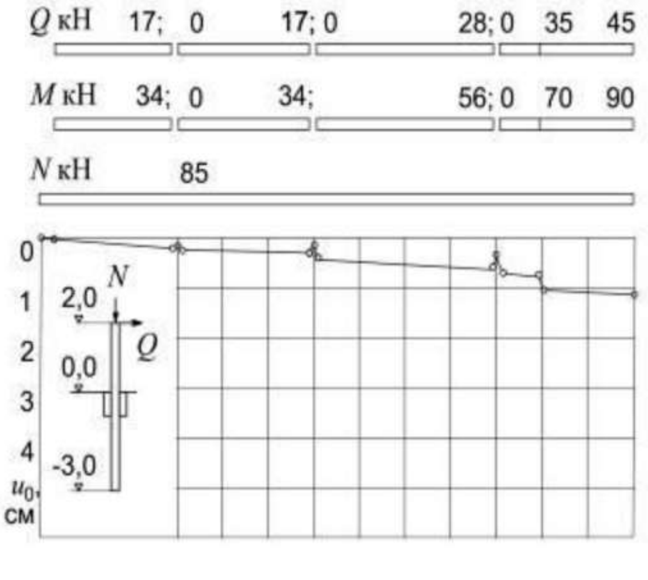

Figure 3 – The graph dependence of the horizontal movements of a pile-column on the load in time

After removing of the horizontal load with a constantly acting vertical force, in the soil there is a decrease in deformation (precipitation and horizontal movement) by the amount of the elastic component of the deformation.

According to the results of the study, it was found that when a horizontal load is applied to the pile - column of the second stage, soil is hardened at a load of Q = 17 kN; M = 34 kN m the elastic component is equal to 58% of the total precipitation and 59% of the total value of horizontal displacements. Under the action of a repetitive force, the magnitude of which does not exceed its initial value, the residual deformations occur in the soil less than their initial value. The primers in this loading cycle are in a hardened state [9, 10]. The strengthening of repetitive loads leads to an increase in the resistance of the soil to external loads and refers to measures that improve its properties.

Conclusions:

1. The studies have shown under the action of loads Q = 45 kN; M = 90 kN m; the elastic component is equal to 27% of the total precipitation and 29% of the total horizontal displacement of the soil.

2. By means the tests it was fixed that the lower boundary of the zone of residual deformations is located at a depth, where the stresses from the load transmitted by the foundation, below its sole, are balanced by its structural strength.

3. It has been established by the tests that, under the action of a horizontal load, the pile is rotated at the point of zero displacements. As a result, the soil in front of the loaded face of the column is compacted; the result of compaction is the movement of the pile, its rotation at the level of the day surface towards the action of forces, and the soles in the opposite direction. The rotation of a pile-column reduces the contact area of the side surface of the pile with the ground. The reduced friction forces cause an additional pile draft.

4. The studies have revealed that after the removing of the horizontal load under the action of a constant vertical force, there is a decrease in precipitation and horizontal movement by the amount of the elastic component of the deformation.

5. By means of the tests it has been established that when applying repetitive loads to previously compacted soil, it is strengthened, i.e., the resistance of the soil to external forces increases, which refers to measures that improve its properties.

References

1. Gersevanov N.M. Theoretical foundations of soil mechanics and their practical application / N.M. Gersevanov, D.Polin. – M.: Stroyizdat, 1958. – 248 p.

2. Tsytovich N.A. Questions of the theory and practice of construction on weak clay soils / N. A. Tsytovich // Proceedings of the All-Union Conference on Construction on Weak, Water-Saturated Soils. – Tallinn, 1965. – P. 5 – 17.

3. Tugayenko Y.F. Soil deformation processes in foundations, piles and pile foundations. monograph / Y.F. Tugayenko. – Odesa: Astroprint, 2008. – 195 p

4. Tugayenko Y. Peculiarities of the soil deformation process at the bases of experimental settlement plates / Y. Tugayenko, M. Marchenko, A.Tkalich, I.Mosicheva // Technical journal Scientific professional journal of University North. – March, 2015. – Vol. 9, №1. – P. 40 – 46.

5. Tugaenko Y. Differential metod of estimation of soil resistance characteristic according to the pile test / Y. Tugayenko, A. Tkalich, M. Marchenko, L. Loginova // Scientific professional journal of University North. – June, 2015. Vol. 9. № 2. — P.180 – 185.

6. Osama A. Safaqah. The Elastomer Gage for Local Strain Measurement in Monotonic and Cyclic Soil Testing / A. Safaqah Osama, F. Riemer Michael // Geotechnical Testing Journal. – March 2007. – Vol. 30, Issue 2.

7. Terzaghi K. Soil Mechanics in Engineering Practice. / K. Terzaghi, R. Peck. – Moscow: Gostransizdat, 1958. – 608 p

8. Geurze E.C.W.A. Rheological and Soil Mechanics / Geurze E.C.W.A. IUTAM Simposium Grenoble 1964. – Springer-Verlag, Berlin, 1966. – P.256 – 270.

9. Tan Tjong-Kie. Three-dimensional theory of consolidation and clay layers / Tan Tjong-Kie // Scientia sínica. 1957. – N5o01. – P.203 – 215.

10. Tan Tjong-Kie. Determination of rheological parameters and clay hardening coefficients / Rheology and Soil Mechanics / Tan Tjong-Kie // STAM Symposium Grehol 1964. Springer-Verlag, Berlin, 1966. – P.256 – 270.