Research of deformation raft-pile foundations under regime cyclic loading

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ABSTRACT

The study's results of the impact of the variable cyclic load on the model of the raft-pile foundation are given. Based on the experimental studies results, the dependences of settlement and defamations under block cyclic loading are obtained. The analysis of graphical dependencies shows that the stresses in the soil and piles change during the process of loading.

Keywords: raft-pile foundation; regime cyclic loading; deformations; grounds of the base

1 INTRODUCTION

In modern conditions at construction of buildings and structures, trend of increasing loads to the ground base and using as a base weak grounds contributed to the fact, that one of the common ways to increase bearing capacity and reduce settlement, using raft-pile foundations. This foundations and their ground bases together with static, exposed to cyclic loads, which in some cases are the main, determine safety using of buildings and structures. Herewith the question of regime cyclic loads influence to the raft-pile foundations behavior researched not enough.

In this regard were conducted experimental and theoretical researches of raft-pile foundations under regime cyclic loading.

2 EXPERIMENTAL AND THEORETICAL RESEARCHES

Experimental studies were carried out in a volumetric laboratory tray with dimensions 100x100x100 cm (Fig. 1). Modeling theory was used to study of the raft-pile foundation behavior.

Fig. 1. Laboratory test tray.

The grillage model of the raft-pile foundation was a reinforced concrete slab with dimensions 40x40x4 cm. The armature of this grillage model was made of wire with a diameter 3 mm. The base soil model was plastic sandy loam (deformation modulus E = 3.5 MPa, internal friction angle 33 °, specific adhesion C = 3 kPa, density p = 1.45 g / cm^3, humidity W = 11%).

The soil sensors showed deformations between piles space and the space below the piles tip. Hollow plastic tubes with the parameters 0.7 cm in diameter, 40 cm long and 0.1 cm wall thickness were the model of piles. Tensoresistors (strain gauges) were glued along the entire length and determined the deformation of the piles. The layout of the sensors and piles are shown in Figure 2. Strength and deformation characteristics of the pile model: compressive strength R_c^* = 92.0 MPa; modulus of deformation E_{com} = 7000 MPa. In experimental studies the raft-pile foundations model have the number 30 piles with the step 7d (where d is the diameter of the pile). The installation of piles was carried out by layer-by-layer dumping and compaction of the soil between the piles. Depending on the regime of testing, a stepwise loading of the model of the raft-pile foundation with a hydraulic jack was carried out.

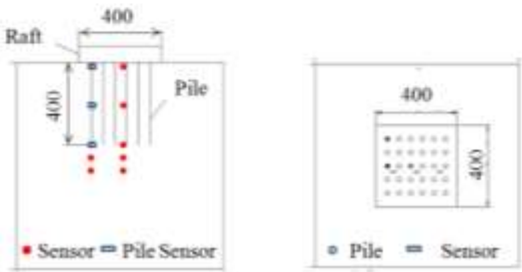

Fig. 2. Layout of piles and soil sensors.

During the experimental studies, the settlement of the raft-pile foundation, the deformation in the special piles (corner, average or central), the deformation of the soil between piles and under the tip of the piles were recorded. Analysis of the deformed state of raft-pile foundation base under regime cyclic loading process allowed to establish the basic laws. Diagrams of block regime cyclic loading are shown in Figure 3.

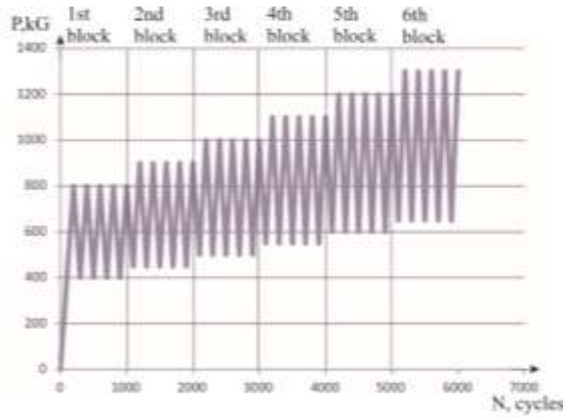

Fig. 3. Block loading mode.

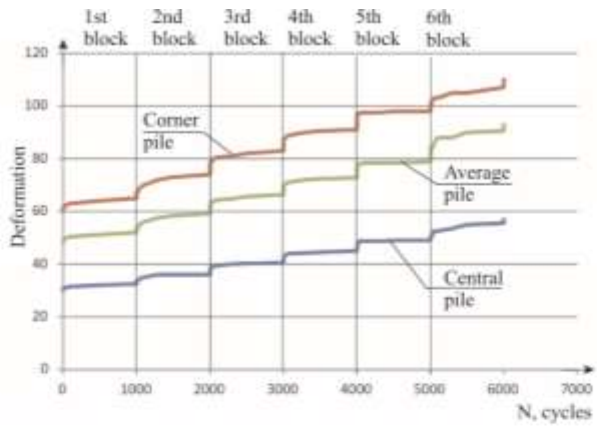

Fig. 4. Deformations (ε*10^{-5}) in piles under regime cyclic loading at a level 2 cm from the sole of the raft grillage.

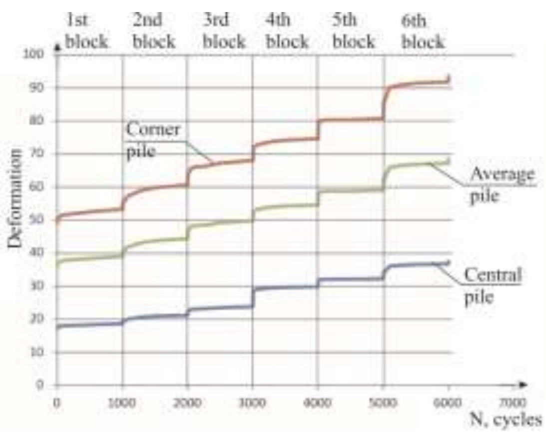

Fig. 5. Change of deformations (ε*10^{-5}) in piles under regime cyclic loading at a level 20 cm from the sole of the raft grillage.

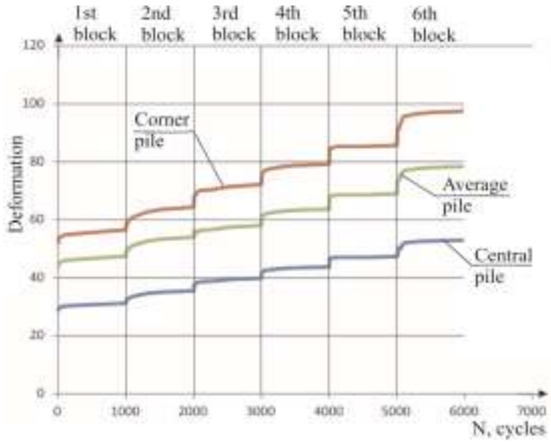

Fig. 6. Deformations (ε*10^{-5}) in piles under regime cyclic loading at a level 40 cm from the sole of the raft grillage.

The change in deformations (ε*10^{-5}) in piles, which are located in the characteristic zones of the raft-pile foundation is shown in Figures 4-6. As it can be seen from this figures, the regime cyclical loading leads to an increase deformations in piles. At the same time, significant deformations in piles occur in the first cycles of the first loading block (up to 200-300 cycles). On the following cycles stabilization of deformations in the piles occurs. The greatest pile deformations occur in their upper zone. For example, in the corner pile on the 1st cycle of the first block the relative deformation is 60*10^{-5}, on the 300th cycle the relative deformation of the corner pile in the upper zone is 63,5*10^{-5}, then the deformations stabilize and at the end of the first block (last cycle) relative deformation is 65*10^{-5}. At the moment of transition to the next block of loading an intermittent increase in deformations occurs by 10^{-5} and then deformations develop similarly to the first block. Within the second block, the deformations increase over 1000 cycles is 9*10^{-3}. During the transition to the following blocks, the above described patterns of the development of deformations were repeated, but in each subsequent block the intensity of the development of deformations decreases.

The authors constructed strain changes graphs in different zones of soil between piles (Fig. 7-9). As can be seen from these figures, there is an increase in soil deformations in all zones of the soil as the number of loading cycle's increases before 200–300 cycles. With the further cyclic loading, the deformations in the soil between piles stabilize. It should be noted that the greatest increase in deformations occurs in the ground under the raft grillage and decreases in depth. Thus, for example, in the upper zone of the soil space between piles at the level 2 cm from the foundation raft on the 1st cycle of the first block, the relative deformation is 48*10^{-5}, on the 300th cycle 50.8*10^{-5}, then the deformations stabilize and at the end of the last cycle of the first block relative deformation is 52*10^{-5}.

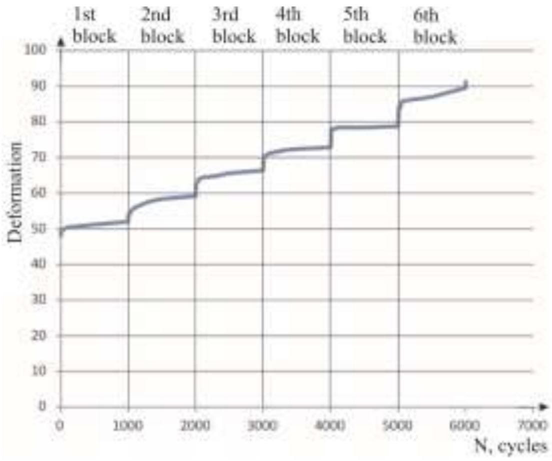

Fig. 7. Deformations ($\varepsilon*10^{-5}$) in the soil between the pile under regime cyclic loading at a level 2 cm from the raft sole.

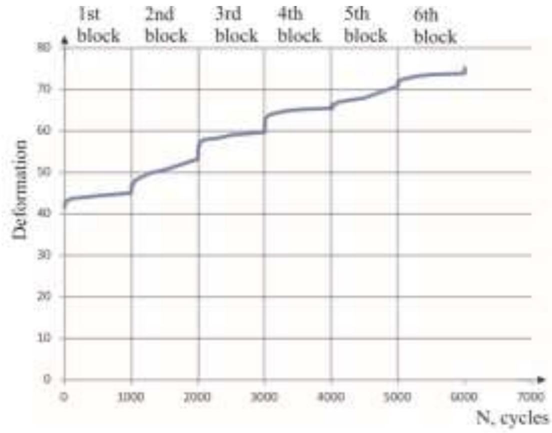

Fig. 8. Deformations ($\varepsilon*10^{-5}$) in the soil between the pile under regime cyclic loading at a level 20 cm from the raft sole.

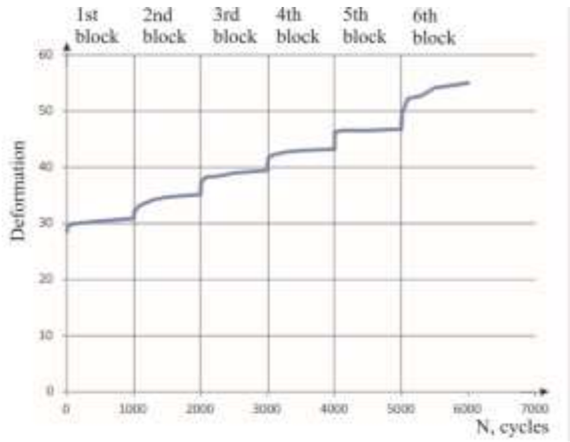

Fig. 9. Deformations ($\varepsilon*10^{-5}$) in the soil between the pile under regime cyclic loading at a level 40 cm from the raft sole.

At the moment of transition to the next block of loading, an intermittent increase in the relative deformations of $0.8*10^{-5}$ occurs and then the deformations develop similarly to the first block. In the second block, the increase in deformations per 1000 cycles is $7.2*10^{-5}$. When moving to the next blocks, the above-described patterns of the development of deformations were repeated, but in each subsequent block the deformations development intensity decreases.

Figures 10 and 11 illustrate changes of deformations in the soil base of pile field below piles' tips. At the first stages of the regime cyclic loading, the soil deformation in the plane of the piles' tips exceeds the values of the soil deformations between piles. When the load is close to the limit, the soil deformation under the piles increases significantly. For example, in the first block, the load on the first cycle of soil deformation (10 cm below the piles tip) is $60*10^{-5}$, on the 300th cycle of the first block the deformation is $75*10^{5}$ and at the end of the first block the relative soil deformation under the piles tip is $76*10^{-5}$. When moving to the following blocks, the above-described patterns of relative deformations development were repeated. In each subsequent block, the deformation development intensity decreases.

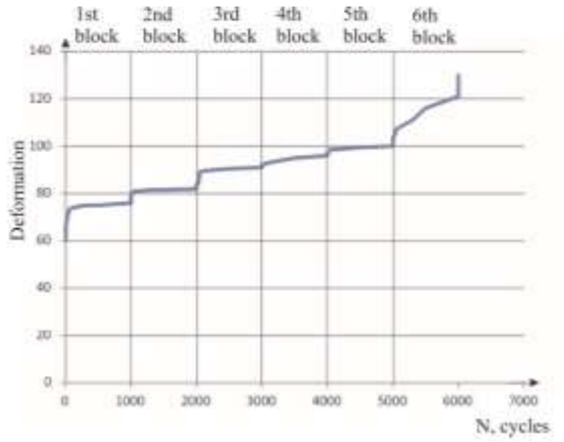

Fig. 10. Deformations ($\varepsilon*10^{-5}$) in the soil under regime cyclic loading at a level 10 cm below the pile tip.

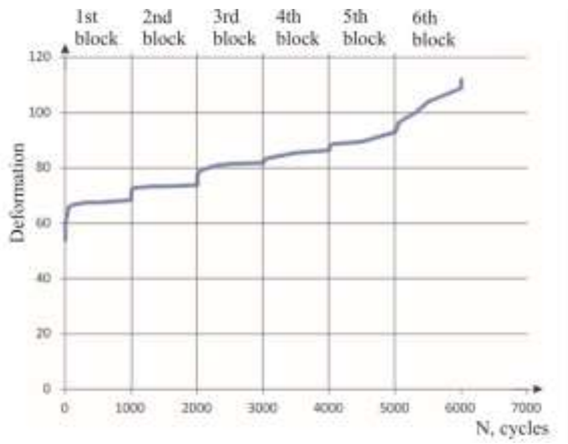

Fig. 11. Deformations ($\varepsilon*10^{-5}$) in the soil under regime cyclic loading at a level 20 cm below the pile tip.

Comparing the deformations under the raft grillage of the raft-pile foundation with the deformations under the piles tip, obtained that the deformations under the piles tip in the first cycle of the first block load increase by $12*10^{-5}$, on the 300th cycle - by $14.2*10^{-5}$ and at the end of the first block - at $14*10^{-5}$. Further, in the transition to the next blocks of loading, the patterns are repeated, but with a lower intensity of the deformations development.

The graph below shows the settlement under the regime cyclic loading (Fig. 12) and the settlements development within each loading block (Fig. 13). Compaction deformations in the initial stage are realized in almost all zones. The increment of compaction deformations after 300 cycles of loading practically stops, which caused a decrease in the intensity of the settlements growth rate, however, the nature of settlements on the following loading blocks remains. The base settlements, measured in the loading process after a different amount of reloading, change similarly to the soil deformations between piles and under the pile tip.

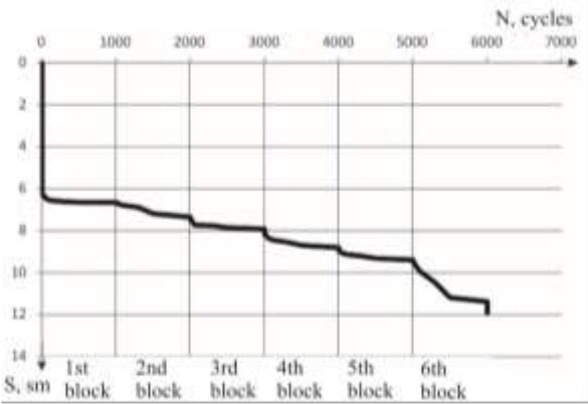

Fig. 12. Base deformations under regime cyclic loading.

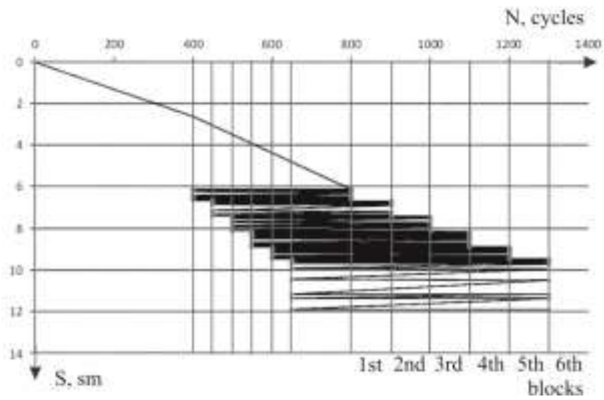

Fig. 13. Settlement development of raft-pile foundation under regime cyclic loading on various loading blocks.

The deformation modulus of the soil in a zone below a pile tip decreases to 71% of the initial, while in the space between piles it increases to 122% of the initial deformation modulus. After conducting experiments and analyzing the carrying capacity of the raft-pile foundation for each experiment, it can be said that the loss of carrying capacity is mainly due to the limiting state of the soil below the piles tip.

After various numbers of cyclic loading blocks, ground base settlement changes analyze shows that the main settlement increment occurs by increasing their residual part (Fig. 13). The deformation increase compare to the first loading cycle up to 30% (Mirsayapov and Shakirov 2014).

Stress-strain pile base condition of raft-pile foundation is very complicated. In this bases, together deform materials with a different strength and deformation properties (Mirsayapov and Koroleva 2015). Deformation development of pile base under regime cyclic loading will take place in the conditions of ground and piles interaction in connected conditions:

a) to the free deformation of the ground is constrained by piles;

b) to the free deformation of the piles prevents the surrounding ground.

As a result of this interaction between the elements in the pile base occurs is an additional stress state and take place a redistribution of efforts between the ground and the piles under regime cyclic loading. The stress in the piles increases, but stress in the ground between the piles reducing compare to the first cycle (Mirsayapov and Koroleva 2011, 2014).

3 CONCLUSION

Under regime cyclic loading, deformations occur in the piles, in the soil in the space between piles and below the piles tip. Deformations in piles and soil between piles are stabilized in the first block (after 300 cycles) and further development of settlement occurs due to deformations of the soil mass below the piles tip. Loss of bearing capacity occurs after reaching the ultimate state of the soil below the piles tip.

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