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Effective Structures of Tamped Foundations of Frame Buildings

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Abstract. The application results of foundations in a tamped ditch in complex geotechnical conditions are strongly considered. The article informs about the experience of the effective foundation application instead of pile foundations. Also, a special attention is given to stress-strain analysis in the active zone of the soil basement of the foundation in a tamped ditch. The article exposes innovative technology of transformation the soil materials structure. Presents the results of studies of innovative soil materials state in the field of geotechnics and foundation engineering. This article seems to be interesting for those who work in the field of building construction and geotechnics.

1 Introduction

Recently in construction practice the quick-mounting houses with a metal framework and reinforced concrete overlapping and covering find application. As walls heat-effective sandwich panels are used. The traditional solution of the frame building foundations in complex geotechnical conditions are pile foundations made from big length piles. The available domestic designing of the foundations in similar soil conditions indicates on an opportunity and advisability of the fullest use of the bearing capacity of tamped foundations [3, 4, 5]. The most reasonable structures of the frame building foundations in complex geotechnical conditions are tamped foundations [1, 2, 3].

Experimental results demonstrate that tamped foundations have the bearing capacity by 2.0-2.5 times bigger in comparison with the prismatic pile of equal volume [6]. The significant increase in the bearing capacity is explained by a large soil compression and the other nature of spatial interaction with the foundation basis in comparison with prismatic piles [7, 8].

2 Technological features, experimental and theoretical results

2.1 Technological features of the foundation making

Tamped foundations are made by the pile engine installation equipped with the diesel hammer and the conical operating element (fig. 1a). At a tamping of ditches a metal tamper

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by the size of 900 mm on top, 200 mm low, 2.5 m long, working by the principle of a wedge with spring-return was used (fig. 1b). The optimum size of the ditch lateral face inclinations to a vertical makes 0.14-0.20 [9].

The spring mechanism is used to avoid the exception of jamming, suction of a tamper in the basis and its extraction from the soil. The principle of the device operation while tamping foundations is shock-mechanical.

The conical tamper is fastened to the guideway with the bracket, and the impact action from the diesel hammer is transferred to the operating element through the cap. During the work of the diesel hammer as a result of the repeated impact action the conical tamper plunges into the soil basis. When the reaction pad achieves the surface of the soil, pad springs begin to contract, and at the moment when the cumulated compressive force of the pad springs become bigger than friction forces and the surface coherence of the operating element upon the ditch walls, there is a separation of a conical tamper from the soil.

Due to the work of the baseplate which is located along the perimeter of a tamped ditch, the ground softening, soil loosening and its uplift is excluded in the area next to the surface of the ditch. (Fig. 2, 3)

a b

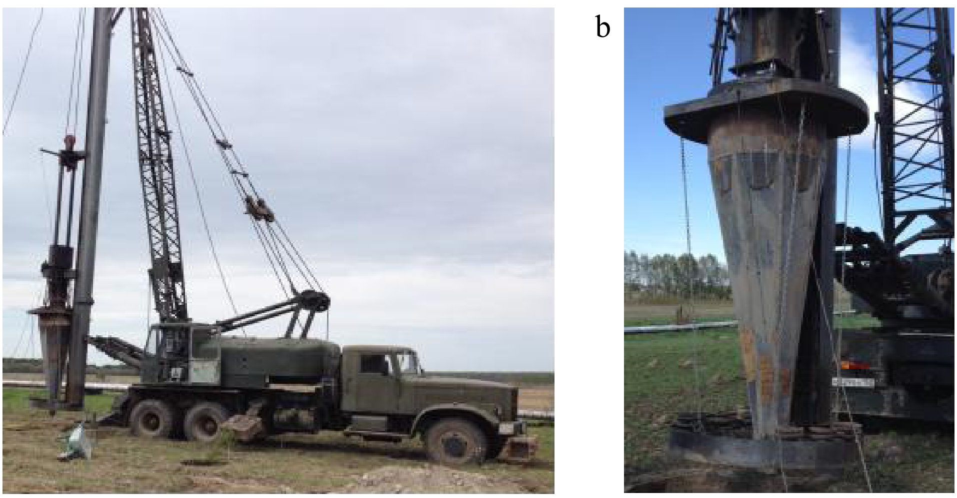

Fig. 1. (a) pile engine; (b) metal tamper.

a b

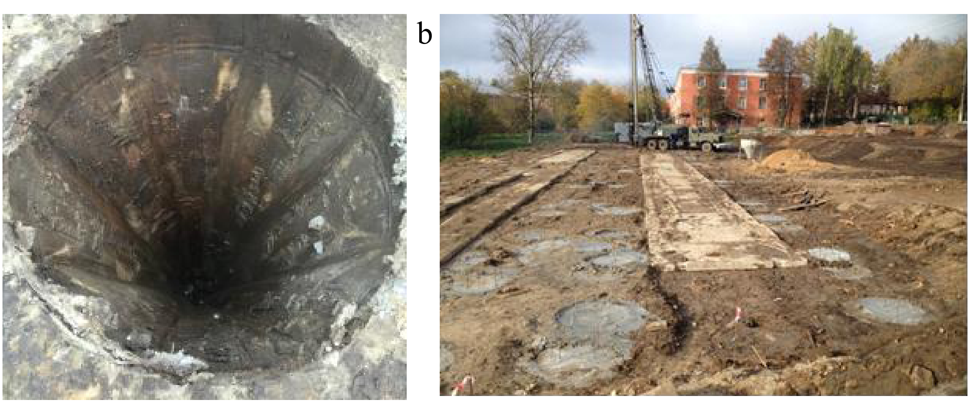

Fig. 2. Ditch (a) after tamping; (b) after concreting.

Fig. 3. (a) metal frame; (b) with reinforced concrete overlapping and covering.

The process of tamping is followed by soil compression with the formation of the compaction zone around the sidewalls and is lower than the plane of a metal tamper connected with the creation of a new structure and the reduction of the void ratio e [10].

At a tamping of a ditch there is an elliptic compaction zone which increases the soil density and improves strength and deformation properties. The control of the soil density in the basis of shallow foundations is determined by the soil resistance to penetration of a micropenetrometer tip in it.

The thickness of a packed layer under the certain foundation in a tamped ditch makes (1.6-2.2)bm below the plane of the cone edge, the width of the compaction zone makes (2.2-2.6)bm respectively, where bm is a diameter of a tamped ditch on an average depth section. The density of the packed soil at a depth of 20-30 cm from the bottom of the tamped ditch makes ρd = 1.70-1.75 g/cm3 at a moisture degree of the packed soil Sr = 0.6-0.7, and ρd > 1.75 g/cm3 at Sr < 0.6. In a packed soil volume after the tamping of ditches in the basis the specific cohesion of soil C increases by 5-7 times, the module of deformation E0 increases by 2-5 times. The depth where the density of the dry soil reaches the value is usually ρd = 1.60 g/cm3, it is accepted as the lower bound of the compaction zone. The greatest efficiency of packing is reached in case of tamping of ditches at the optimum moisture content ω0, and is determined by the formula:

$$\omega_0 = \omega_p - (0.01 \div 0.03) \tag{1}$$

where ωp is a plastic limit.

2.2 Experimental and theoretical investigation of the bearing capacity

Full-scale tests of the deformable foundation basis in the tamped ditches reflect the aspects of spatial interaction of frame buildings and the basis more precisely. In-situ experiments in full-scale conditions were made on three grounds for the purpose of a reliable assessment of the bearing capacity of tamped foundations.

The experimental ground No. 1 of an apartment frame house is located in Ufa. According to the geomorphological investigations the site is related to the III left-bank terrace valley of the river White. The geological section of a site of researches up to the explored depth of 15.0 m is presented by quaternary, neogen sediments. On top there is loam (adQ) from semisolid to stiff consistence with an opened power of 3.5-7.8 m. Loam is spread by semisolid clay (N23-Q1) of a thick layer of 2.1-10.2 m and sand of average fineness with the power up to 2.0 m. From the depth of 8.0-12.0 m clay is semisolid, neogen (N2ak).

The experimental ground No. 2 of a hostel where 277 people live is located in Nizhny Novgorod. In the geomorphological relation the ground (platform) is in the centre of the East European Plain, on the contact point (interface) of the Western part of the Volga Highlands, the Volga-Vetluzhsky Plain and the Mari Lowland. Sediments of the Perm (P2) and quaternary (Q) systems take part in a geological structure of the working area up to the depth of 60.0 m. In the soil profile of the explored ground (platform) up to the explored depth the following engineering- geological elements are met: IGE 1 – technogenic formations (tIV) – are presented by the mixture of resedimented sand and sandy loam of grey colour; IGE 2 – blanket layer of loams (pr, d, II-III); IGE 3 – alluvial fluvioglacial sediments (and, f, IIdn) – fine-grained sand, clay with fine gravel of metamorphic rocks. Ground waters are assumed at a depth of 2-5 m from the earth's surface.

The experimental ground No. 3 of a dwelling house is located in the town Reshetikha of the Nizhny Novgorod Region. In the top part of the alluvial layer of loams under filled-up soil lie quartz (adQIII), fine-grained sands and sands of average density with the power up to 7.7 m. Quarternary layer loams are spread by the formations of Urzhumsky tier of Central Perm and put by stiff clays and siltstones. Below at the depth of 56 m lie karstic carbonate rocks and sulphatic breeds of the Kazan and Sakmarsky tiers of Central and Low Perm.

Experimental investigation of the bearing capacity of tamped foundations were carried out according to State Standard 5686-2012 Soils. "Field test methods by piles" [11]. For the ultimate strength of the tamped foundation there is a loading under the pressure of which the tested foundation has received the settlement equal to s and is determined by the formula (2):

$$s = \zeta \cdot S_{u,mt} \tag{2}$$

where $S_{u,mt}$ – the limiting value of the foundation settlement of the designed frame building is established according to the BC 22.13330, $S_{u,mt}$ = 15 cm (civil buildings with metal frame) [12];

ζ – transfer factor from the limiting value of the foundation settlement of the building Su, mt to the settlement of the tamped ditch, ζ = 0.3.

A structural design load on the pile foundation is determined by the formula:

$$N = \frac{F_d}{\gamma_k} \tag{3}$$

where γ_k is the safety factor on soil for the bearing capacity of the tamped foundation according to the results of field test methods by the static load, γk = 1.0.

Thus, taking the results of static tests, the calculated load on the tamped foundation of frame buildings is defined at settlement S within 45 mm.

Theoretical studies of the bearing capacity of tamped foundations are made with the use of the geotechnical complex Plaxis. The spatial elastoplastic analysis was carried out by the method of final elements with the simultaneous accounting of strength and deformation properties of the basis [13, 14]. As yield condition while carrying out the analysis the limit equilibrium equation of Mohr-Coulomb was accepted [15, 16]. The design model of the basis considered the formation of the compaction zone while tamping a ditch.

The dead load of soil was carried out in the form of initial stresses, the deformed condition of the basis was defined only from the external load on the foundation [17].

Matching conditions of the soil basis are 8.0×8.0×12.0 m (fig. 4). Under the loads on the frame column more than 750 kN the foundation is made from two combined tamped ditches with the monolithic reinforced concrete capping.

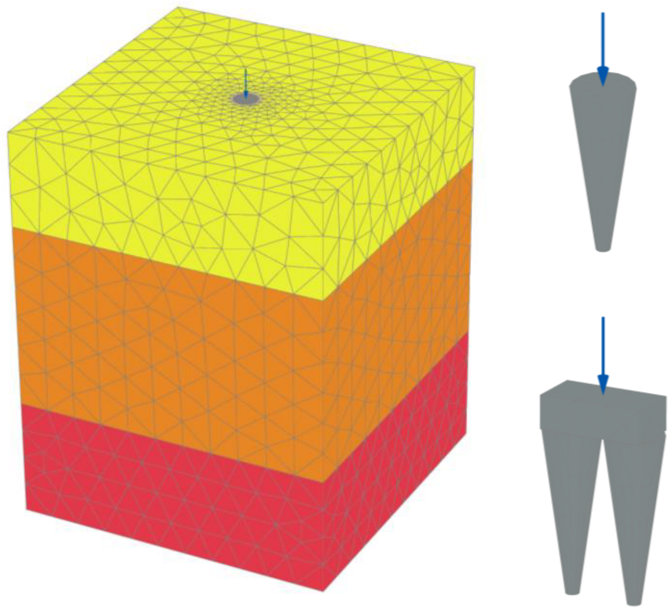

Fig. 4. A design model of the method of final elements.

Comparison of the results of experimental and theoretical investigations of the bearing capacity of tamped foundations on experimental grounds No. 1, 2, 3 is given in fig. 5-10.

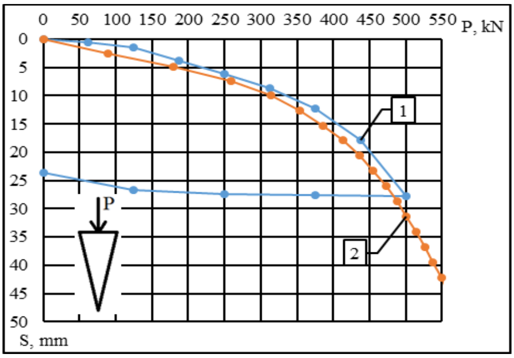

Fig. 5. Dependence of S=f (P) for platform No. 1:
1 – experiment; 2 – calculation.

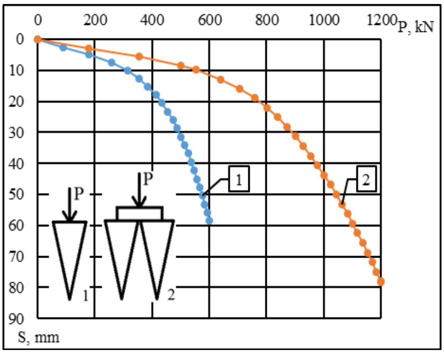

Fig. 6. Results of the calculation of tamped foundations:
1 – single; 2 – double (platform No. 1).

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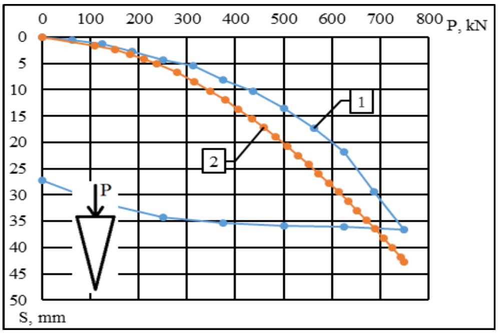

Fig. 7. Dependence of S=f (P) for platform No. 2:
1 – experiment; 2 – calculation.

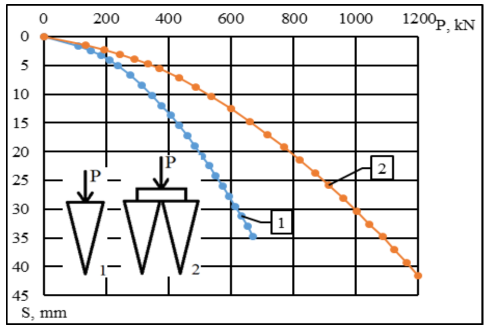

Fig. 8. Results of the calculation of tamped foundations:
1 – single; 2 – double (platform No. 2).

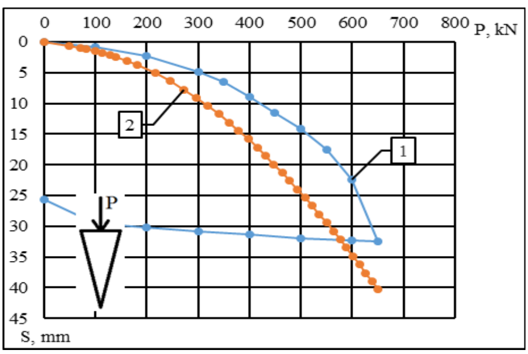

Fig. 9. Dependence of S=f (P) for platform No. 3:
1 – experiment; 2 – calculation.

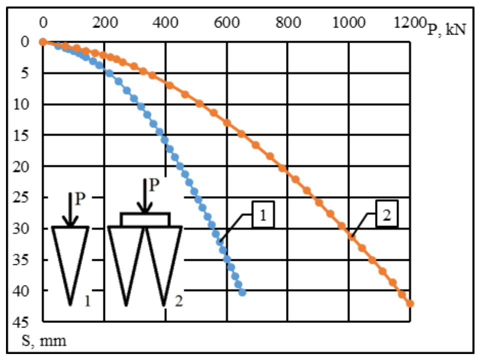

Fig. 10. Results of the calculation of tamped foundations:
1 – single; 2 – double (platform No. 1).

For the increase of the bearing capacity of the tamped foundation a solid material is tamped into the foundation ditch. It allows to increase the area of the spread foundation below the plane of the cone edge and leads to the increase of the bearing capacity by 1.2-1.5 times (fig. 11) [18, 19].

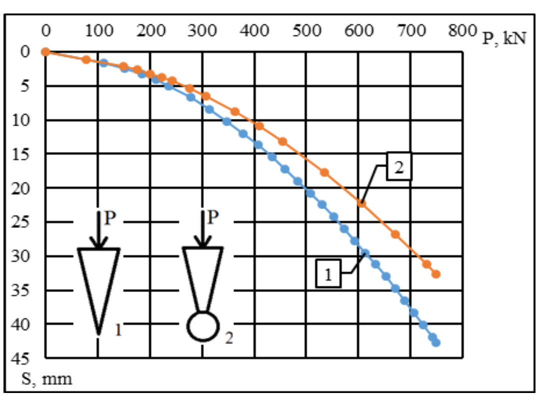

Fig. 11. Dependence of S=f(P) of the ditch on platform No. 2 (1) without tamping of crushed stone and (2) with tamped crushed stone in the bottomhole of the cone edge

3 Conclusion

The use of tamped foundations for frame buildings allows to reduce material capacity of a zero cycle by 1.5-2.0 times, to reduce the volume of excavation and shuttering works. The load carrying capacity of the foundations in tamped ditches on experimental grounds No. 1, 2, 3 makes 820-1120 kN/m3 that is significantly bigger than for traditional foundation designs. The use of nonlinear mechanics of soil allows to estimate the stress-strain state of tamped foundation bases in the high dynamic range of changing the loads up to their limits [20]. For the practical application the engineering method is allowed to determine the tamped foundation settlement taking into account the strength and deformation properties of soil. As the mathematical model, connecting the value of settlement with the initial parameters the multifactor nonlinear dependence is accepted. It allows to design tamped foundations by using maximum permissible deformations.

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