The bearing capacity of the explosive piles’ bases: the bases granular media geomechanics theory

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Abstract. The material of the scientific work is presented in two articles: “The bearing capacity of the explosive piles’ bases: the bases granular media geomechanics theory” and “The bearing capacity of the explosive piles’ bases: geotechnical design of rational structures”. The foundations granular media foundations geomechanics theory development and the innovative scientific technical problems integrated solution relevance is grounded. The purpose and objectives of the scientific research are defined. The main content of the research presented a brief justification of the results. The theory of geomechanics includes the principles of the theory of nonlinear soil mechanics of granular media of the foundations and non-linear mechanics of the soil of granular media of the foundations of single piles. The theory of geomechanics is intended for use as fundamental factors in the development of geotechnical engineering for the design of rational designs of ramming explosive single piles and foundations.

Introduction
In modern industrial and civil construction, pile foundations are considered to be the most popular due to their unparalleled dignity. The main bearing structural element of a pile foundation is the piles of various types. Experience shows that the most promising type is rammed piles, which were made on site in fully primed wells with various technical means. At present, the well-known technologies for the production of stuffed piles in ground-pressed wells with a diameter of up to 500 mm have been mastered. This diameters size restriction is due to the reason for the soil driven piles foundations granular soils powerful resistance overcoming capable technical means lack to the significant concentrated loads from the structures. The solution of the technical means causing problems is associated with the possibility of manufacturing, as a type, promising progressive innovative single piles-foundations that satisfy any design values of the concentrated loads from the structures of the above-ground structures. In this regard, the author has developed, created and tested an innovative constructive and technological solution for the explosive soil priming of wells for the ramified explosive piles manufacture with the diameters up to three meters of their trunks strictly cylindrical straight-line shape rational structures and with axisymmetric cupboards broadening of the lower ends of the individual form, arranged in case of design necessity.

An explosive pile is a rod-like structure in the ground, made in an explosive-high-explosive well by the concrete mix reinforcement and free-laying with its sufficient compaction without stuffing.

Comparative studies field results of the carrying capacity of pilot drilling and ramming explosive piles with a diameter of 216 mm and a length of about three meters in the same soil conditions showed
the bearing capacity excess of explosive piles relative to drilling piles by 1.8 times. The calculated studies using the traditional soil mechanics methodologies have shown a significant underestimation of the carrying capacity compared with the experimental data, which necessitated the granular foundations soils non-linear mechanics innovative fundamental theory creation or “The grain media foundations geomechanics”, which allowed to get the results of theoretical calculations, comparable in accuracy with the experimental ones [1].

At the same time, these piles designing rational structures explosive pile foundations hinders granular media geomechanics limits the developing theory creation due to the comprehensive solution of the scientific and technical problem geo-engineering lack and, consequently, their widespread use in modern foundation engineering. Therefore, the purpose of this article is to develop a theory of the granular grounds geomechanics of. The goal defines the objectives of the study in the composition:

- the explosion products’, well generator and the ground energy-controlled system action mechanical interaction theory development;
- the granular media foundations non-linear mechanics innovative theory creation;
- the piles granular bases soils nonlinear linear mechanics innovative theory creation.

The vertically loaded stuffed explosive single piles-foundations bearing capacity is formed in the sedimentary mechanical soil process displacing its own bases.

The main content of the study is presented in a brief justification of the obtained scientific results. The main significant findings of the study are described.

The ramming explosive single piles-foundations physically maximum possible resource bearing capacity realization further innovative fundamental direction prospect is formulated.

**Brief content of the bases foundations grain-barried media geomechanics theory main agreements**

The vertically loaded explosion-fused piles subsequent sedimentary mechanical soil displacement theoretical substantiation pile foundations and scientific primary well-forming explosive-high-explosive soil displacement scientific and technical support development allowed to create an innovative fundamental scientific theory of non-linear and the granular media foundations soil-tones non-linear mechanics or the theory of “The granular media foundations geomechanics” [2]. The scientific principles of the granular media foundations geomechanics theory are applicable to the bases of explosive single piles, bored single piles, small foundations, single-wavy-slab foundations and other types.

The main provisions of the granular media foundations geomechanics include the following:

The explosion products, the wellbore generator and the soil energy-controlled action system mechanical interaction theory [3 ... 7]:

- the hull, surface and soil statics;
- the wellbore and soil system dynamics;
- a high-explosive and a well-casing in the ground kinematics;
- condensate vacuum pressure in the chambers and in the associated camouflet cavities.

The die bases and single piles sandy soils granular powdered clay nonlinear mechanics main provisions theory, including:

- the shifting soils strength characteristics physical mechanical and mathematical essence theoretical substantiation;
- the use of granular media as a mechanical behavior model;
- the stamp containing experimentally investigated sandy base deformation theoretical differential analysis:
  - the soil elastic, plastic, viscous and rigid separate calculated graphs deformations;
  - obtaining reference stepwise coefficients of the soil non-linear general, elastic, plastic, viscous and rigid deformations moduli proportionality;
- determine the dies and single piles load-bearing bases soil state phases according to the well-known concepts of the active compaction pressure action and the passive decompaction pressure in the contacts between the displaced soil particles;
- The theory of interaction in the processes of physical and mechanical formation of five zones of states of limiting equilibria and equilibrium angles of the granular soils inner thorn at the single pile base.

The single piles bases’ granular media limiting equilibria in the zone of the five zones states soils stress nonlinearity theory in the composition [8]:
- theoretical model of the single pile being loaded with the surrounding soil force interaction;
- the shifting sand particles engagement internal friction stiffness resistance force stresses degree indicators in the mineralogical compositions of soils;
- theoretical features of mechanical interaction in the contacts of shifted mineral soil particles under load;
- substantiation of the workers of the total main normal compressive and tangential shear stresses along the pile shaft side surface.

The theory of the single piles bases granular media limiting equilibria states five zones area soil deformation nonlinearity can be shown in the following representation [9, 10]:
- The main provisions of the model of the theory of nonlinear deformation of extremely stressed soils;
- Experimental and theoretical substantiation of the compacted soil cores forms in the base of the stamp and the lower end of a single explosive pile: a tangenoid of rotation, pyramidal tangensoid, a circular cone;
- geometric parameters and their relationship for the choice of the soil stressed and deformed states physical equations;
- nonlinearity of common, elastic, plastic, viscous and rigid deformations of extremely stressed granular soils in the single piles’ bases.

The explosive piles bases’ granular media ultimate equilibria states five zones area granular soils nonlinear linear mechanics theory contains:
- the bases by vertically loaded piles subsequent sedimentary mechanical soil priming design-technological model position;
- the soil limiting equilibrium states zones choice, involved an experienced explosive fuse pile;
- the blasting pile foundation granular soils implementing the ultimate bearing capacity and stability possibility substantiation;
- the limiting equilibria states five zones area granular soils pile shaft stress compression non-linear-linearity computational research methodology;
- the high explosive pile foundation load precipitation on the nonlinear linear dependence calculated graph theoretical construction.

The methodology of theoretical design studies, methodology and methods for calculating the carrying capacity nonlinear linearity and the granular soils deformation in the explosive pile bases granular media limiting equilibrium states five zone includes:
- The methodology for the ramming pile base granular soils carrying capacity and deformation design study in a punched well, as applied to an explosive pile;
- the limiting equilibria zonal states its compression by the stresses’ vertical loadable explosive piles pressure in granular soils generation theoretical substantiation base;
- the minimum compression pressure high-explosive pile with the generation base and stabilized sediment limiting equilibria states five zones granular soils in the zone maximum bearing capacity methodology;
- the high-explosive pile limiting equilibria of bases and stabilized sludge states five zones granular soils critical bearing capacity methodology a with the maximum compression pressure generation.
The theory and methods of geomechanics knowledge are used as the fundamental factors for the geotechnical engineering development for designing rational structures of the packed explosive single piles-foundations.

**Design-theoretical nonlinear-linear schedule of the draft dependence on the explosive-fog piled loading**

Using the calculated values of critical loads $P_i$ and the corresponding values of stabilized $S_i$ sediment, an example of constructing a theoretical non-linear-linear graph of precipitation versus load $S_i = f(P_i)$ according to the calculated research data shown in Table 1 is given, for a medium explosive pile with a diameter of 0.8 m and a length of 12.0 m in silty clay.

| № point | 1    | 2    | 3    | 4    | 5    |
|---------|------|------|------|------|------|
| $\sigma_i$, [kPa] | 23.0 | 60.8 | 117.8| 204.0| 345.1|
| $P_{ki}$, [kN]     | 30.9 | 81.5 | 158.0| 273.5| 462.8|
| $P_i$, [kN]        | 1464.0| 1884.9| 2426.3| 3238.8| 4483.2|
| $S_i$, [kN]        | 5.1  | 7.8  | 59.0 | 159.5| 318.0|

According to the design load on the pile $P_d$, the corresponding stabilized pile draft $S_d$ is determined graphically.

**Figure 1.** The estimated graph of precipitation versus load $S_i = f(P_i)$ of an explosive ramming pile: 1 - non-linear 1 ... 3 zones of states of limiting equilibrium soil; 2 - linear 3 ... 5 zones

The prospect of further innovative fundamental directions for the implementation of the physically possible maximum bearing capacity based on packed explosive single piles-foundations is to be realized by means of the initial preliminary limit base stress by pressing the ground from the original...
explosive well to the final volume the design well, as well as the material of the pile shaft, and the subsequent sedimentary mechanical soil displacement of the base by circular cones of conditions a wide massive basement and a lower end of a vertically loaded explosive pile.

**Summary**

For the first time, an innovative fundamental theory of granular foundations geomechanics has been created.

The following sections have been developed in the foundations’ granular media geomechanics composition.

Mechanical interaction of the explosion products energy-controlled action system borehole generator and soil.

Nonlinear mechanics of granular dust-clay and sandy soils of the bases of the strains and single piles-foundations.

Nonlinearity of soils stress in the area of five zones of the single piles bases grained dispersed, discrete-discrete and discrete environments limiting equilibria states.

Nonlinearity of soil deformation in the area of single piles granular media limiting equilibria states five zones.

Nonlinear linear mechanics of granular soils in the area of the explosive-damped single piles-foundations granular media bases limiting equilibria states five zones.

Methodologies of theoretical design studies, methodology and methods for calculating the nonlinear linearity of bearing capacity and sedimentary-deformation displacements of soils in the area of the foundations explosive single piles granular media limiting equilibria states five zones.

The theory of geomechanics ensures the perfect agreement between the experimental data and design definitions results by objectivity.

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