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THE LATEST TRENDS IN THE CREATION OF IMPACT-VIBRATION EQUIPMENT WITH DIFFERENT TYPES OF DRIVES FOR SOIL PROBING

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The study of soils by immersion of a cone under the influence of ultrasonography is one of the express methods of obtaining engineering and geological information about the physical and mechanical properties of the foundation from loose soils of buildings and structures. It makes it possible to detect the degree of homogeneity of probed soils; determine the position of the boundaries (contacts) of various lithological layers and bearing layers for the fuel base; to identify and delineate in plan and in depth the weakened zones on the studied areas for the exact reference of the place of conducting experimental works; choose the optimal options for choosing hammers; evaluate the physical and mechanical properties of sandy soils (density, angle of internal friction, etc.); roughly estimate the modulus of deformation of sandy soils.

The main tasks are the development, research and calculation of the main parameters of installations with a hydraulic impulse drive for soil probing.

The object of research is the process of soil probing. The subject of the study is the hydropulse drive of the soil probing installation.

Experience has shown that the effective use of field methods is possible only under the condition of a methodically correct approach to the preparation and execution of programs of the entire complex of search operations. Various aspects of the problem of comprehensive soil research using field methods were developed and deepened gradually.The main research methods include the analysis of information on existing methods and installations for spraying tungsten powders, mathematical modeling of processes in the spindle unit of the installation for spraying metal powders, taking into account its design features and operating modes based on nonlinear differential equations of heat transfer from solid and liquid bodies using numerical methods of their solution based on the FlowVision program.

***Key words**: complex, functionality, equipment, processing process, soil.*
F. 25. Fig. 14. Ref. 7.

1. Introduction

The study of soils by immersion of a cone under the influence of ultrasonography is one of the express methods of obtaining engineering and geological information about the physical and mechanical properties of the foundation from loose soils of buildings and structures. It makes it possible to detect the degree of homogeneity of probed soils; determine the position of the boundaries (contacts) of various lithological layers and bearing layers for the fuel base; to identify and delineate in plan and in depth the weakened zones on the studied areas for the exact reference of the place of conducting experimental works; choose the optimal options for choosing hammers; evaluate the physical and mechanical properties of sandy soils (density, angle of internal friction, etc.); roughly estimate the modulus of deformation of sandy soils[1-7].

2. Formulation of the problem

The latest trends in the creation of shock-vibration equipment with different types of drives for soil probing. An integral element of the project and estimate work in construction is engineering and geological surveys. In recent years, field methods of studying the physical and mechanical properties of soils have been introduced into the practice of engineering-geological investigations at an increasing pace.

The tendency to use a complex of field methods in the study of physical and mechanical properties of soils began to manifest itself from about the mid-1950s, when various field methods of soil research, including dynamic and static sounding, radioactive logging, camouflage explosions, etc. Experience has shown that the effective use of field methods is possible only under the condition of a methodically correct approach to the preparation and execution of programs of the entire complex of search operations. Various aspects of the problem of comprehensive soil research using field methods were developed and deepened gradually.

The idea of integration of field methods developed in two directions: by parallel application of different methods within the study site and by creating combined installations that allow simultaneous examination of soils on the same vertical by different methods.

Such classifications have a certain significance, however, in the case of engineering and geological research of soils with a complex of field methods, it is more expedient to base it on a more complete and more general classification, which determines the possibility and feasibility of applying a complex of field methods at different "scales": from two to three types of field methods of one subgroup or several methods of different subgroups and groups to combine different classes and types of field methods. In this work, there is no need to dwell on the detailed characteristics of individual field methods. At the same time, it is advisable to pay attention to some features of at least a few of the most common methods, which must be taken into account when using them in the practice of engineering and geological investigations.

First of all, one should consider the nature of soil research by field methods at the depth of the studied area. The vast majority of field methods are characterized by fragmentary research. Thus, soil sampling from boreholes, radiometric measurements, soil testing with stamps, pressure gauges and many other methods are carried out periodically (Fig. 1, a, b). At the same time, the distances between exploration horizons, tests and soil tests are several tens of centimeters, and sometimes several meters. At the same time, under certain conditions, there is a danger of passing through a layer with properties that differ from the properties of the surrounding soils[1-7].

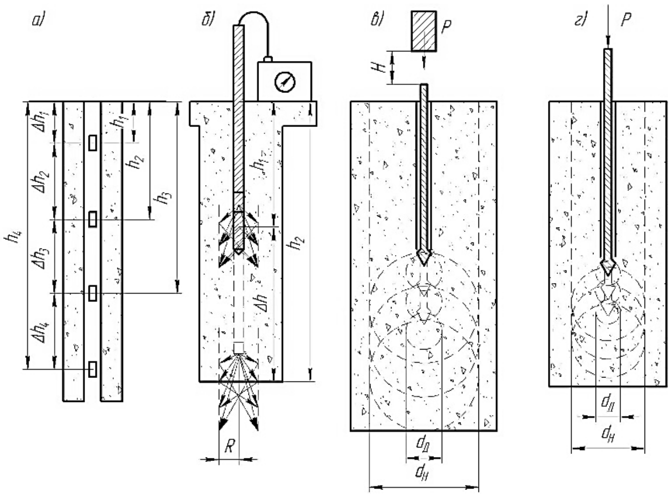


Fig. 1. Schemes illustrating different methods of soil study:
a – borehole passage with sampling; b – radioactive logging; c – dynamic sounding;
d – static probing.

Notations: *H* – depth of sampling or radioactive measurements; *Δh* – soil test depth intervals; *R* – the depth of the radioisotope method; d_d – diameter of the zone of deformation and destruction of the soil structure; d_n – the diameter of the zone of change in the stress state of the soil.

A different volume of the studied soil is characteristic of almost all field methods, including sounding methods. At the same time, it is important to take into account not only the volume of the soil deformation zone, but also the dimensions of the zone of change in the soil stress state, which plays a significant role, for example, when assigning the averaging zone of soil test data to establish correlations between the indicators of soil tests by different methods. As you know, there are different field methods and techniques for studying the same soil properties.

Recognizing the progressiveness of the explosive sounding method, it should be noted that the above questions can be resolved only on the basis of a joint study of soils by a complex of field and laboratory methods. The method of field description and documentation of soils, strictly speaking, is mandatory when conducting engineering-geological investigations, but sometimes it is underestimated, therefore it is not included in the program of works, which works are carried out in insufficient detail and carefully. The value of these data is difficult to overestimate: in some cases, only on their basis it is possible to correctly interpret the results of soil tests, to trace the susceptibility of soils to the so-called additional weathering[1-2].

The emergence and development of shock-vibration sounding as a new method of soil research was due to the development and wide implementation of dynamic (shock) sounding in the production, as well as the development of the shock-vibration method of drilling engineering-geological wells.

Shock-vibration sounding of soils can be carried out with the help of any installations and units equipped with shock-vibration or a shock device for immersing various elements into the soil. Hammers, vibro-immersers and vibratory hammers with various types of drives are usually used in such installations, but mostly these are Soviet-made vibratory hammers with unbalanced drives.

Drill pipes and a conical tip are used as the main tools for shock-vibration probing of soils.

In principle, a standard tool for dynamic probing (according to CH 448-72) can be used for shock-vibration probing. However, this tool should only be used in combination with a low-power vibratory hammer.

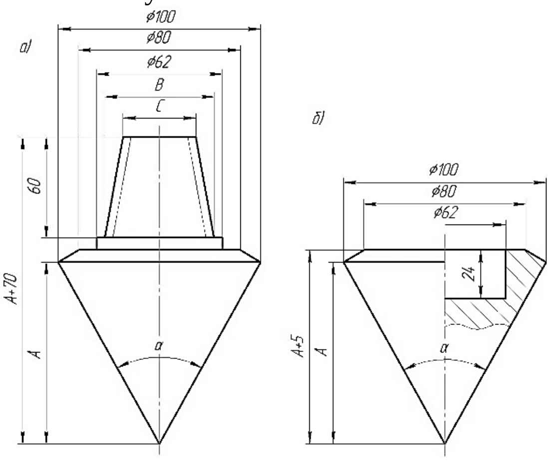


Fig. 2. Inventory (a) and removable (b) conical tips for shock-vibration probing of soils

Classification of vibratory hammersit is carried out according to the type of drive used, as well as the presence of an elastic connection between the vibration exciter and the immersed element. Vibrohammers differ from vibroimmerses in the way of connecting the body of the vibrating exciter with the head through spring shock absorbers, which allow the body of the vibrating exciter to oscillate with large swings, breaking away from the head and hitting the hammer on the anvil during the return movement.

Hammers consist of a massive impact part that moves forward relative to the guide structure in the form of a cylinder (pipe), a piston with a rod, rods, etc. The impact part of the hammer makes alternating blows on the head of the pile and sinks the pile into the soil. The guide part of the hammer is equipped with a device for fixing and centering the hammer on piles[1-2].

Vibro-immersing machines are divided into machines of longitudinal and longitudinal-rotational action according to the form of disturbed vibrations; according to the scheme of the device - for machines of the simplest type and with a spring-loaded load; according to the type of energy used - for machines with an electric and hydraulic drive; according to the presence of a transmission - on transmission (there is a transmission between the engine and unbalanced shafts) and transmissionless (engine shafts are unbalanced shafts); by purpose and field of application - for high-frequency and low-frequency vibro-immersing devices.

The main advantages of low-frequency vibratory submersibles in comparison with percussive means of submersion are also higher submersion speeds (in weak and medium-density soils), simplicity and convenience of management, and less complex auxiliary equipment.

The material of the pile during vibration immersion, without being exposed to shock loads, experiences much lower stresses, which allows the use of a vibratory immersion machine for immersion of thin-walled reinforced concrete shells to a great depth. The vibro-plunger can be used when plunging piles near structures without fear of breaking their integrity, as the surrounding soil vibrates less in this case than during impact plunging. In addition, vibratory submersibles work almost silently. The main disadvantage of this type of vibratory submersibles is that they can work effectively only in weak, water-saturated unbound or loosely bound soils. In dense soils, for example, in clays, their sinking ability decreases sharply, and sometimes sinking becomes impossible. The mass of the element immersed by the vibration method is practically unlimited. There is a well-known experience of vibratory immersion of a casing well with a gravity of more than 200 kN. During shock-vibration immersion, the force of gravity of the immersed element, as a rule, should not exceed 3-5 kN, since for the most effective immersion by this method in conditions of significant frontal resistance, the ratio of the immersed element and the impact part of the vibrating hammer should approach unity; the use of a vibrating hammer with a force of gravity of the striking part exceeding 3-5 kN is limited by the durability of the mechanism, which sharply decreases with an increase in the weight of the striking part. since for the most effective immersion by this method in conditions of significant frontal resistance, the ratio of the immersed element and the striking part of the vibrating hammer should approach unity; the use of a vibrating hammer with a force of gravity of the striking part exceeding 3-5 kN is limited by the durability of the mechanism, which sharply decreases with an increase in the weight of the striking part. since for the most effective immersion by this method in conditions of significant frontal resistance, the ratio of the immersed element and the striking part of the vibrating hammer should approach unity; the use of a vibrating hammer with a force of gravity of the striking part exceeding 3-5 kN is limited by the durability of the mechanism, which sharply decreases with an increase in the weight of the striking part.

Machines that transmit shock pulses (when struck by a vibrator) and vibration (due to the elastic connection of the vibrator with the immersion element) to the submersible element or any working body are called vibration-impact mechanisms, and submersible impact machines are called vibrohammers. Vibrohammers can be classified: according to the presence of an elastic connection between the vibration exciter and the immersed element - into springless (free) and spring; on the connection of the engine with the vibration exciter - on transmission and without transmission; according to the type of drive - electric, hydraulic, with an internal combustion engine; according to the type of vibration exciter - for machines with a two-wave exciter and with a single-wave exciter. Vibrating impact machines are advantageously different from vibrating machines in their ability to self-adjust, that is, the ability to increase the impact energy to some extent when the resistance of the medium increases and, therefore, reducing the compliance of, for example, an immersed element. This is explained by the fact that the mode of operation of the vibrating impact machine is strongly influenced by the speed recovery coefficient upon impact, which is the ratio of the speed of the vibrator after the impact to the speed before the impact and depends, in turn, on the ratio of the masses of the co-impacting elements; when immersed in the soil, the mass of the element increases with deepening (in connection with the growth, the mass of the soil joins); this entails an increase in the coefficient of recovery and therefore the energy of the impact and ultimately allows the use of the vibration impact mechanism with greater efficiency. which is the ratio of the speed of the vibration exciter after the impact to the speed before the impact and depends, in turn, on the mass ratio of the co-impacting elements; when immersed in the soil, the mass of the element increases with deepening (in connection with the growth, the mass of the soil joins); this entails an increase in the coefficient of recovery and therefore the energy of the impact and ultimately allows the use of the vibration impact mechanism with greater efficiency. which is the ratio of the speed of the vibration exciter after the impact to the speed before the impact and depends, in turn, on the mass ratio of the co-impacting elements; when immersed in the soil, the mass of the element increases with deepening (in connection with the growth, the mass of the soil joins); this entails an increase in the coefficient of recovery and therefore the energy of the impact and ultimately allows the use of the vibration impact mechanism with greater efficiency [1-2].

Vibrohammers transmit both vibration and impact pulses to the submersible elements and provide immersion in dense soils of metal piles up to 13 m long, metal piles and pipes up to 20 m long. Vibrohammer designs have few differences. Some types of hammers can work both in impact and non-impact modes, depending on the stiffness of the elastic system, vibrator parameters, soil resistance to immersion, etc.

Vibrohammers are also used for immersing reinforced concrete piles in homogeneous water-saturated soils and extracting pipes, piles and sheet piles from the soil.

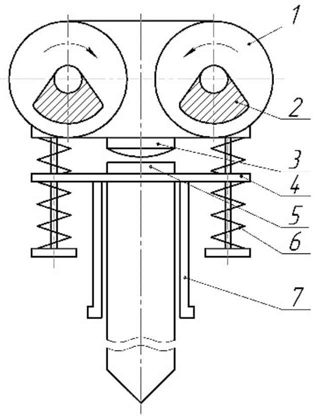


Fig. 3. Schematic diagram of a vibrating hammer

The main elements of the vibratory hammer are the spring-loaded shock part, the lower loading plate and the head. The impact part is (Fig. 3) a two-wave transmissionless vibration exciter 1 of directional vertical oscillations with an impactor 3. Two electric motors are mounted in the body of the vibration exciter, on the parallel shafts of which, rotating synchronously in different directions, unbalances 2 with an adjustable static torque are fixed. The impact part and the lower plate 4 with the anvil 5 are connected to each other by working springs 6. The headpieces 7 are connected to the immersed element rigidly or can be attached to it freely without fastening.

Experience shows that higher-frequency vibratory hammers have a narrower scope of application, as they provide effective immersion of sheet piles and other elements with low frontal resistance only in weak soils. In dense soils, machines that develop significant impact energy are more effective. In fig. 4 presents a number of well-known vibrating hammer schemes.

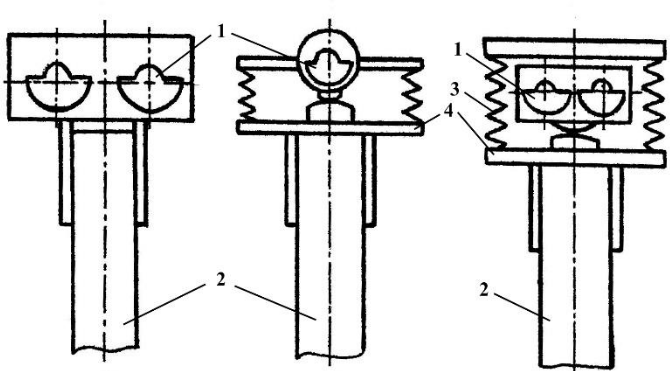


Fig 4. Basic structural diagrams of vibrating hammers

Depicted in fig. 4, and the vibratory hammer is transmissionless, springless with a two-wave vibration exciter 1 of directional action, freely installed on the pile 2. There is no two-way connection between the vibrator and the pile, while the vibrator is also free from external connections. Practically, it consists of two electric motors built into a common rigid body. Imbalances are fixed at the ends of the shafts. According to the nature of the impact on the immersed element, the considered impact-vibration immersion is a high-frequency hammer. The main advantage of such vibratory hammers is the simplicity of the design and, what is especially important, easy and convenient adjustment, which is mainly ensured by establishing the correct ratio between the force of gravity of the vibrator G and the amplitude of the forced force P. For the most efficient and stable mode of operation of the loader, it is quite sufficient that so that the G/P ratio is 0.4-0.5. The disadvantage is the impossibility of independently controlling the mass of the submersible system. The submersible does not have a shock absorber that could serve as a support for the loader, and the rigid connection of the latter with the pile or with the vibrator is impractical. The disadvantages also include the inability to provide normal conditions for the operation of electric motors, which have to be built into the vibrator. In these conditions, it is very difficult to achieve long-term operation of engines.

In fig. 4, b presents a diagram of a transmissionless spring vibrating hammer with a single-wave vibrating exciter of circular action, which, compared to two-wave vibrating hammers, has a smaller mass and a simpler design.

3. Analysis of last researches and publications

Justification of the choice of parameters of the hydroimpulse drive of the installation during soil probing.The basis of the structure is a mass of soil that accepts the load from the structure. In those cases when soils in their natural state serve as bases, such bases are called natural. Soils previously compacted by appropriate methods are called artificial.

In order to correctly solve issues related to the choice of piling equipment for arranging foundations and foundations of buildings and structures, it is necessary to know the main characteristics of soils[1-2].

Soils are rocks that lie in the upper layers of the earth's crust and are used for construction purposes when performing various engineering works. Soils, which are used as foundations for buildings and structures, are divided into rocky, semi-rocky, large-clastic, sandy and clay soils.

Rocky soils include granites, sandstones, cherts, limestones and other rocks. In the absence of external influences of this kind, massive rocks are the strongest foundations for all buildings and structures.

Groundwater, affecting gypsum, limestones, marls, forms cracks and voids in their massifs or causes karst phenomena. Non-cemented soils containing more than half of fragments of crystalline or sedimentary rocks by weight are called large-clastic. This group of soils includes gravel (pebble) and wood (gravel). Such soils do not change their physical properties when moistened, are weakly compressed under load, have significant shear resistance and are weakly eroded by water.

Sandy soils include soils that become loose when dry, do not have the property of plasticity, and contain less than half of the particles larger than 2 mm by weight. Depending on the grain composition, sandy soils (sands) are divided into large, medium, fine and very fine. Quartz, shale and limestone sands are distinguished by their mineralogical composition. Quartz sands are the strongest. The granulometric (grain) composition of the soil shows the relative content of solid particles of different sizes in it, which is expressed as a percentage of the total mass of the studied soil. The granulometric composition is established by analysis, in which the solid particles of the soil are divided into separate groups by size.

Solid soil particles (skeleton) consist of grains of two main types: compact form (sandy soils) and plastic form (clay soils). The specified types of grains affect the physical and mechanical properties of soils. The degree of this influence depends on the percentage content of this type of grain in the soil composition.

One of the main functional mechanisms that determine the performance and reliability of vibration devices as a whole isvibration exciter, which serves to obtain a certain law of oscillations of the working body.

Analysis of designs of vibromechanisms with different types of drives allowed us to conclude that the most fully satisfy the requirementshydraulic vibratory exciters, thanks to which it was possible to significantly expand the scope of technical application of vibrations, including in the case of vibration cutting of metals, because with the help of hydraulic vibratory exciters it is possible to most rationally solve tasks that cannot be solved using other types of vibratory excitersis The study of the patterns of development of vibration equipment with different types of drives showed that the direction of its development is determined by the type of generator of mechanical oscillations (vibrations) of the robotwhose link or vibration exciter. The vibration exciter is the main unit of any vibration machinetires and determines the degree of its perfection, reliability, functionality, cost and other technical and economic indicators.

The following analysis allows us to conclude that indue to the wide development of vibration technology, not all existing types of vibration exciters can satisfy the listed requirements. Especially there are great difficulties associated with increasing the specific power, (carrying capacity) of vibration exciters.

According to the type of drive, modern vibration exciters can be divided into mechanical, electric, pneumatic, hydraulic, combined.According to the principle of operation, hydraulic vibration exciters are divided into the following main types: pulsating, tracking, self-oscillating, self-controlled (Fig. 5).

In self-oscillating hydraulic systems, the excitation is periodicthe force is created by a special device that automatically supplies and drains the working fluid when fed from a constant pressure line.

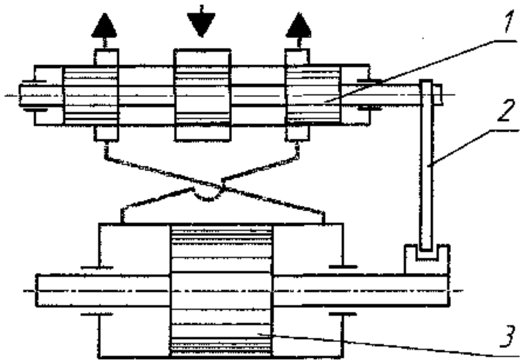


Fig. 5. Schematic diagram of self-oscillating hydraulic vibrator

The creation of a volume-type AGV with a valve distributor is currently at the stage of experimental and industrial samples. Some of the promising designs of vibration exciters of this type and their manufacturing technology, which correspond to specific working conditionsvibration machines, for example, the vibration drive of molding machines, are not sufficiently developed, the theory and methods of calculation have not acquired a complete form and do not correspond to the technical engineering level.Hydraulic vibration exciters with a special oscillation generator — an automatic pressure control device (pulsator valve) not directly connected to the executive mechanism deserve attention. Analysis of known designs of such vibration exciters showed that despite their diversity, the principle of pressure feedback is used to control the switchgear.

One of the schemes of a hydraulic vibration drive with a valve-pulsator is shown in fig. 6.

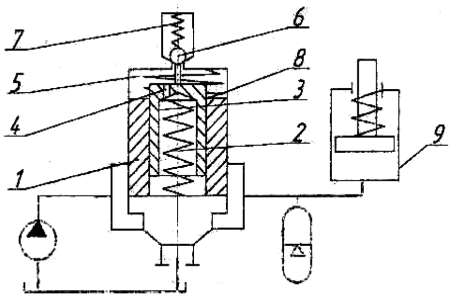


Fig. 6. Diagram of a hydraulic vibration drive with a pulsator valve:
1 – valve of the second stage 2 – spring; 3 – pusher; 4 – throttle hole; 5 – supravalvular cavity; 6 – ball; 7 – spring; 8 – spring; 9 – cylinder cavity

In this scheme to achieve automaticcontrol of the movement cycle of the working body uses a two-stage pulsator valve with a ball closing element of the first stage and a conical one of the second stage, which separatesinjection cavity from the drain line. The principle of operation is that oil enters the working cavity of the pump from the pumpof the grinding cylinder 9 and through the channels made in the body of the second cascade 1, through the throttle hole 4 in the pusher 3 into the supravalve cavity 5. The results of the research showed that in the hydraulic system with the pulsator valve of the proposed design there is an auto-oscillation mode, and the amplitude and the frequency of self-oscillations is significantly influenced by the geometric parameters of the pulsator valve itself and you final mechanism[1-7].

Simplicity of construction, a wide range of adjustment of vibration parameters, lack of seals in translational pairs ensuresuch vibration exciters are used in various technological vibration machines. distribution device and its connection with the executive mechanism.

Let's consider some of the constructions of HBV, which according to the principle of action of analogic of the scheme presented above, however, the self-oscillation unit (pulsator valve) is built into the executive mechanism, which made it possible to simplify the design of the vibration exciter and reduce its dimensions.

A concrete example of placing the pulsator valve in the vykoa system of vibration exciter can serve as a learning mechanism, the scheme of which is shown in fig. 7. This HVV contains a two-stage control element of the valve type, which is mounted in the plunger 2 and isby an oscillation generator made together with the executive mechanism, and the feedback of the control element and the executive mechanismchange is carried out under pressure. This vibration exciter can be recommended to ensure high-frequency load modes.A negative point in the design and calculation of vibration exciters of this type may be the difficulty of analyzing the work process itself.

An attempt to get rid of the distribution device in the form of a spool led to the creation of an original design of a vibration exciter with mechanical feedback on displacement (Fig. 8), whichA two-stage switch is used as a distribution devicepan 5 with a control rod 2 with two pins, the upper one of which Z zhois connected to the hydraulic cylinder (working table) 1, and the lower 4 is connected to the two-stage valve 6. Pins C and 4 interact with the controlrod 2. The vibration amplitude is adjusted by changing the clearances Ai and D2 by turning the eccentric pins 3 and 4. The disadvantages of this design include structural and technicalthe logical complexity of manufacturing the control element, as well as the lack of recommendations for calculating its parameters.

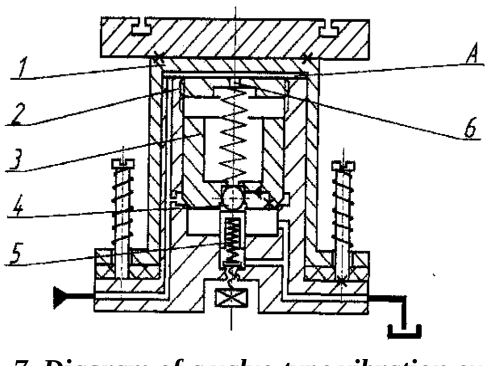


Fig. 7. Diagram of a valve-type vibration exciter with pressure feedback: 1 – hydraulic cylinder; 2 – plunger; 3 – valve; 4 – ballska; 5 – piston; 6 – throttle hole; A – pressure cavity

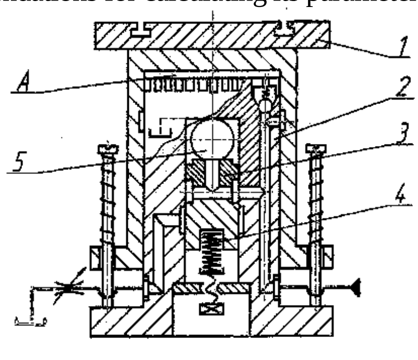


Fig. 8. Scheme of a small-sized hydraulicvibration exciter with spool-type pressure feedback (percussion): 1 – work table; 2 – plunger; 3 – spool; 4 – prugin; 5 – ball

4. The aim of the study

The purpose of the work is to increase the efficiency, speed of operation, as well as the possibility of regulating the soil probing process by developing and using installations with a hydraulic impulse drive .

5. Presenting main material

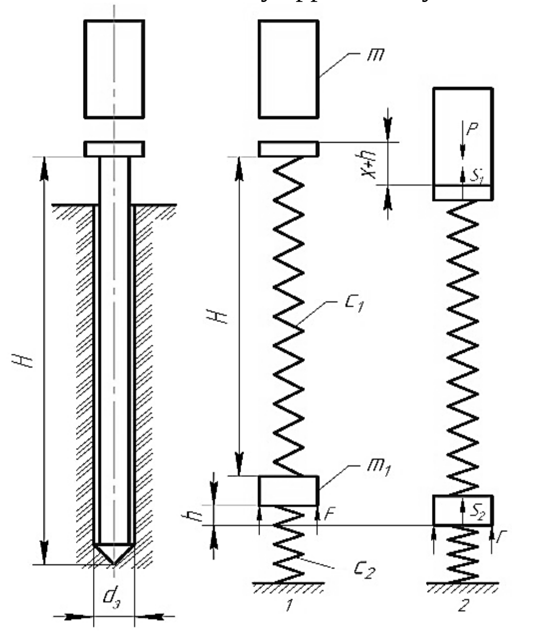
Mathematical model of the shock-vibration soil probing process.Based on the analysis of existing soil models, taking into account the peculiarities of the researched process, the next simplest model of shock-vibration soil probing is proposed. The upper end of the probing projectile (Fig. 1, a), which consists of a cone and drill pipes, is periodically struck with a mass of m. The frequency of shocks is such that before each subsequent shock, the sounding projectile is at rest.

The following assumptions are made:

1. A body of mass m is a completely rigid body.
2. The drill string is an ideal spring with a stiffness coefficient C_1, the mass of which is distributed between the masses m and m_1.
3. The soil is modeled as an elasto-plastic medium without viscous resistances (ie, an ideal spring with a stiffness coefficient C_2 and a constant plastic resistance force of the soil F).
4. The impact is completely inelastic, i.e. the recovery coefficient $R=0$.
5. Wave phenomena that pass through the drill rod are not taken into account.

The maximum deformation h of the soil consists of elastic and plastic components, while both are final, that is, they represent elastic deformations, or more precisely, deformations caused by a force that is proportional to the displacement. Thus, the described process model, having some similar elements, differs from already known models. In particular, according to the schematic diagram of the soil adopted here, deformations proportional to displacement are accompanied by plastic ones.

The elasticity of the probing rod is introduced, however, for the sake of simplicity, the case of a completely elastic and not completely elastic impact is excluded from consideration. The mass of the soil, which absorbs part of the kinetic energy of the impact, is also not taken into account. It is easy to see that the presented model can be fully applied to dynamic soil probing.



a ***b***

Fig. 9. The simplest model of the shock-vibration soil probing process: a – scheme of the projectile; b – elastic-plastic model: 1 – before impact; 2 – after impact

In accordance with the accepted assumptions, only constant forces and forces proportional to the movement act on the mass m1 in the process of its movement, so the theorem on the change in the kinetic energy of the system can be used to find the value of the immersion of the probe per impact. In accordance with this theorem, we write the following equality:

$$\left(mv^2/2\right)-\left(mv_0^2/2\right)=\sum A_к, \quad (1)$$

where m – is the energy of the impact mass: υ_0, υ – is the initial and final velocity of the impact mass movement ($\upsilon=0$); $\sum A_к$ – is the sum of the work of all external and internal forces acting on the system.

The sum of the work of all forces is described by the equations:

$$\sum A_к = A_1 + A_2 + A_3 + A_4; \quad (2)$$

$$A_1 = P\left(x+h\right); \quad (3)$$

$$A_2 = -C_1 \cdot x^2/2; \quad (4)$$

$$A_3 = -C_2 \cdot h^2/2; \quad (5)$$

$$A_4 = -Fh, \quad (6)$$

where A_1 – is the work of the weight P of the shock mass and the drilling projectile on the displacement $x+h$; x – deformation of spring C_1 (probe rod); A_2 – work of elastic force of spring C_1; A_3 – work of elastic force of spring C_2; A_4 – operation of constant resistances F.

Substituting the expressions (3) – (6) into formula (2) and taking into account that υ=0, we obtain:

$$\frac{-m\upsilon_0^2}{2} = P\left(x+h\right) - \frac{C_1 x^2}{2} - \frac{C_2 h^2}{2} - Fh, \tag{7}$$

and after conversion:

$$\frac{m\upsilon_0^2}{2} + P\left(x+h\right) = \frac{C_1 x^2}{2} + \frac{C_2 h^2}{2} + Fh. \tag{8}$$

In the left part of equality (8) - the kinetic energy of the impact mass and the work of weight, in the right - the work of elastic deformation of the probing rod, soil deformation caused by a force proportional to the displacement, and the work of plastic resistances.

From the condition of the equality of the mass m1 under the action of a constant force applied to the upper end of the spring C_1, the equality holds:

$$C_1 x = C_2 h + F. \tag{9}$$

Neglecting the mass m_1, which is insignificant, we obtain:

$$x = \frac{C_2}{C_1} h + \frac{F}{C_1}. \tag{10}$$

Substituting formula (10) into formula (8), we get:

$$m\upsilon_0^2 + 2P\frac{C_2}{C_1}h + 2Ph = \left(C_2 h + F\right)\left(\frac{C_2}{C_1}h + \frac{F}{C_1}\right) + C_2 h^2 + 2Fh, \tag{11}$$

and after conversion:

$$C_2\left(C_1 + C_2\right)h^2 - 2h\left(C_1 + C_2\right)\left(P - F\right) - \left[m\upsilon_0^2 C_1 - F\left(F - 2P\right)\right] = 0. \tag{12}$$

Calculating the equation (12) with respect to h, we obtain:

$$h = \frac{P-F}{C_2} + \sqrt{\frac{\left(P-F\right)^2}{C_2^2} + \frac{C_1 m\upsilon_0^2 + F\left(2P - F\right)}{C_2\left(C_1 + C_2\right)}}. \tag{13}$$

In formula (13), value C_1 represents the stiffness coefficient of the drill rod. In the process of soil probing, the length of the probing rod changes and, as a result, its stiffness coefficient changes.

Let's present the valueC_1expression:

$$C_1 = C_1'/H, \tag{14}$$

where C' – stiffness coefficient per unit length of the foundation rod; H is the length of the probing rod.

Then expression (13) can be written in the form:

$$h = \frac{P-F}{C_2} + \sqrt{\frac{\left(P-F\right)^2}{C_2^2} + \frac{C_1' m\upsilon_0^2 + HF\left(2P - F\right)}{C_2\left(C_1' + HC_2\right)}}. \tag{15}$$

Formula (15) allows you to calculate the value of the submersible probe per impact depending on the parameters included in it. It is obvious that the frequency of blows n per unit of time is known, it is easy to determine the immersion speed of the vibroprobe using the formula:

$$\upsilon_в = nh. \tag{16}$$

In some cases, the probe is hammered by impact, which are describedexpression (15), are the following:

1. The plastic supports of the soil are small, i.e. F=0:

$$h = -\frac{P}{C_2} + \sqrt{\frac{P^2}{C_2^2} + \frac{C_1' m\upsilon_0^2}{C_2\left(C_1' + HC_2\right)}}. \tag{17}$$

2. The weight of the shock mass and the probing rod is small compared to the plastic and elastic resistances of the soil, i.e. P=0:

$$h = -\frac{F}{C_2} + \sqrt{\frac{F^2}{C_2^2} + \frac{C_1' m\upsilon_0^2 - HF^2}{C_2\left(C_1' + HC_2\right)}}. \tag{18}$$

3. The plastic resistance of the soil is insignificant, the weight of the shock mass and the probing rod are also small, that is, F=0 and P=0:

$$h = \upsilon_0 \sqrt{\frac{C_1' m}{C_2 \left(C_1' + H C_2 \right)}}. \tag{19}$$

4. The soil has virtually no elastic properties, i.e. C2=0. To determine h in this case, it is necessary to use expression (17), then:

$$h = \frac{-m\upsilon_0^2 C_1' - HF\left(2P - F\right)}{2C_1'\left(P - F\right)}. \tag{20}$$

Expression (20) is valid if F > P.

The considered model also allows obtaining the criterion of normal immersion and the maximum length H of the sounding rod, at which the process of immersion (for the given parameters) is suspended.

From expression (12), it is easy to establish that the immersion process will not occur:

When P ≠ 0

$$-m\upsilon_0^2 \le \left[\left(F^2 - 2PF \right) / C_1 \right]; \tag{21}$$

When P = 0

$$m\upsilon_0^2 \le F^2 / C_1. \tag{22}$$

Value*Hmax*, at which the immersion process will stop, can be determined by the formulas:

When P ≠ 0

$$H_{\max} = \left[\left(m\upsilon_0^2 C_1' \right) / \left(F^2 - 2PF \right) \right], \tag{23}$$

When P = 0

$$H_{\max} = \left[\left(m\upsilon_0^2 C_1' \right) / F^2 \right]. \tag{24}$$

Interestingnote that the maximum length of the projectile, at which the probe will not sink into the soil, does not depend on the resistance of the soil, which is proportional to the displacement, that is, on C_2.

The value of the initial immersion of the probe for the impact corresponding to the case when *N*=0, neglecting the weight of the shock mass and the probe is determined by the formula:

$$h = -\frac{F}{C_2} + \sqrt{\frac{F^2}{C_2} + \frac{m\upsilon^2}{C_2}}. \tag{25}$$

The obtained formulas, despite their simplicity, allow us to closely approach the question of the interpretation of the data of impact and UDF sounding of soils.

Development of a hydraulic impulse drive of a soil probing installation.The obvious advantages of the hydraulic impulse drive over the mechanical drive allow to increase the productivity of the installation as a whole, and also allow mobile use of the equipment without being tied to a specific unit[1-2]. The developed scheme of a hydraulic hammer with a built-in vibration exciter is presented in fig. 10.

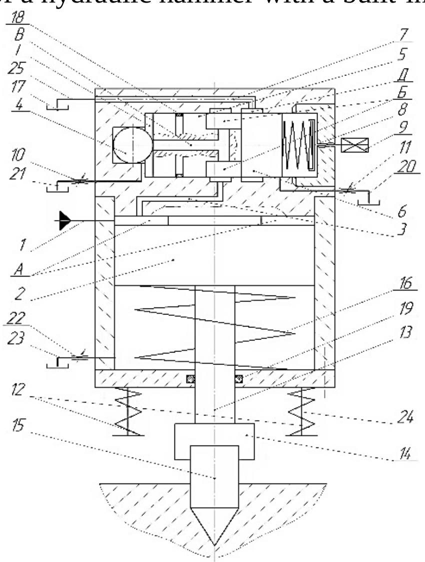


Fig. 10. Schematic diagram of a hydraulic hammer with a built-in vibration exciter

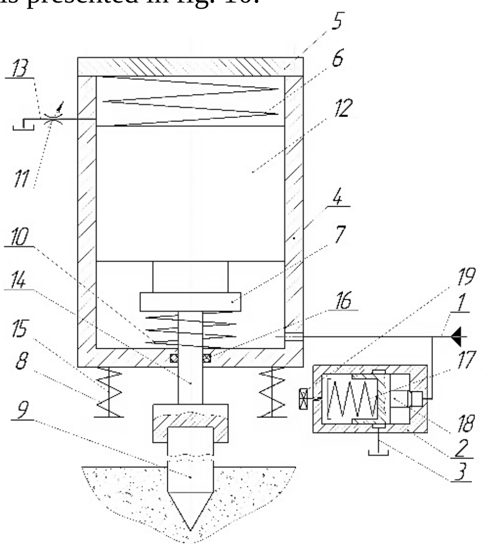


Fig. 11. Schematic diagram of a hydraulic hammer with a single-stage vibration exciter

Springs 12 mounted on pins 24 are designed to return piston 2 to its original position. A ball 4 is installed in the seat of the groove of the vibrating hammer body, which is pressed by the spool 5, creating a small contact area between its channel B and the cavity G. The piston 6 is pressed against the spool 5 by a spring 8, which can be adjusted using the adjusting screw 9. Channel 7 connects the cavity D drain hydraulic line 25, through which the working fluid enters tank 1. Throttle 10 is connected to hydraulic line 23 and is used for easy starting of the vibratory hammer. Throttles 11 and 22, as well as hydraulic lines 21 and 23, are intended for draining the working fluid that can accumulate in the spring installation cavity 9 and 16, respectively.

The developed hydraulic hammer with a single-stage vibration exciter (Fig. 11) consists of a pressure line 1, a single-stage pulsator valve and the working cavity of the hydraulic hammer cylinder. The pulsator valve is connected to the pressure 2 and drain 3 lines. In the housing 2 of the pulsator valve, there is a spool 18, pressed by a spring 17, the pressing force of which is regulated by a screw 19. The piston 12 is installed in the housing 4, and is pressed by a spring 6.

The developed hydraulic hammer with a two-stage vibration exciter (Fig. 12) consists of pressure line 1 to which a two-stage pulsator valve is connected, which in turn is connected to pressure line 2 and drain line 3, and through pressure line 2 it is connected to the working cavity of the cylinder hydraulic hammer In the body of the two-stage pulsator valve, there is a valve 22 pressed by a spring 26, and a sleeve 25 pressed by a spring 19. A valve with a pusher 20 is pressed by a spring 23. The compression force of the spring 23 is regulated by a screw 21. The piston 12 is installed in the housing 4 of the cylinder of the hydraulic hammer, and is maintained in the initial position using a spring 10.

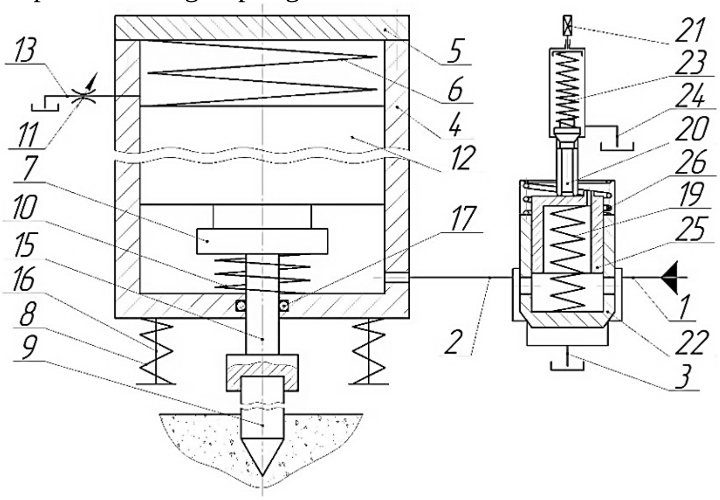


Fig. 12. Schematic diagram of a hydraulic hammer with a two-stage vibration exciter

The housing 4 is hermetically closed with a cover 5. The striker 7 is rigidly connected to the rod 15 and the vibrating probe 9. The springs 8 are mounted on the pins 16 and are intended to return the piston 12 to the initial position. The spring 10 supports the striker 7 in the initial position and acts as a damper. Throttle 11 and main line 13 are intended for draining the working fluid that can accumulate in the spring installation cavity 6. To reduce leaks through the gap between rod 14 and housing 4, a sealing ring 16 is used in the vibratory hammer. Cover 5 is screwed to housing 4 and facilitates easy assembly of the hydraulic hammer.

The developed hydraulic hammer with a hydraulic accumulator and a built-in vibration exciter (Fig. 12) consists of pressure line 1 to which a two-stage pulsator valve is connected, which in turn is connected to pressure line 2 and drain line 3, and through pressure line 2 it is connected to the working the cavity of the hydraulic hammer cylinder. In the body of the two-stage pulsator valve, there is a valve 22 pressed by a spring 26, and a sleeve 25 pressed by a spring 19. A valve with a pusher 20 is pressed by a spring 23. The compression force of the spring 23 is regulated by a screw 21. The piston 12 is installed in the housing 4 of the cylinder of the hydraulic hammer, and is maintained in the initial position with the help of a spring 10. The body 4 is hermetically closed with a cover 5. The striker 7 is rigidly connected to the rod 15 and the vibration probe 9. The springs 8, mounted on the pins 16, and are designed to return piston 12 to its original position. The spring 10 supports the striker 7 in the initial position and acts as a damper. Throttle 11 and main line 13 are intended for draining the working fluid that can accumulate in the spring installation cavity 6. To reduce leaks through the gap between rod 14 and housing 4, a sealing ring 16 is used in the vibratory hammer. Cover 5 is screwed to housing 4 and facilitates easy assembly of the hydraulic hammer.

The principle of operation of the hydraulic hammer consists in the fact that the hydraulic fluid enters the pressure channel of the hydraulic hammer through the pressure line 1, and causes an increase in the pressure in it. In parallel with this, the working fluid enters the hydraulic accumulator 5, where additional energy of the working fluid is stored. The increase in pressure in the pressure channel contributes to the movement of the ball piston 6 and the spool 7. When the pressure in the pressure channel exceeds the set opening pressure, the pressure channel 2 and the working cavity 4 of the hydraulic hammer are connected, which leads to an instant increase in the pressure in the working cavity 4 of the hydraulic hammer, and rejection piston 15. This mode of operation is typical for submersible hammers and rammers, which act on the soil at the end of the stroke of the moving parts at the moment of mass collision. The design feature of this pulsator valve consists in increasing the pick-up area of the pusher due to the placement in the axial boring of the main valve 4 of two coaxial pushers 5 and 7, rigidly connected to each other by a cylindrical spacer 6 with a T-shaped channel. However, this design does not allow for costs up to (10 - 15)10^{-3} m^3/min to get a valve pulsation frequency of more than 10 - 15 Hz.

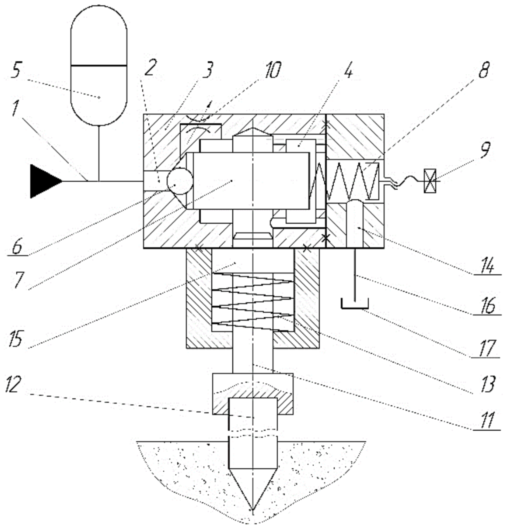


Fig. 13. Schematic diagram of a hydraulic hammer

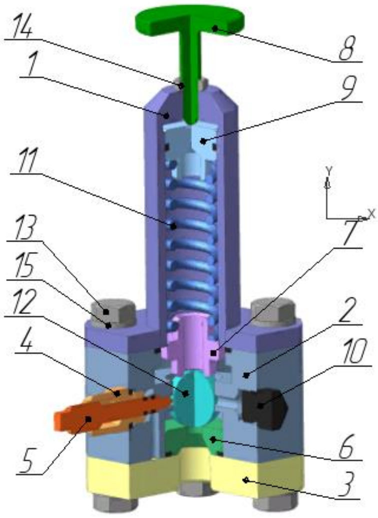


Fig. 14. Use of numerical methods based on the FlowVision program

A fairly simple solution has been found to control a hydraulic impulse drive that does not require a wide range of adjustment and that has some back-up pressure in the drain line. At the same time, an inertial single-cascade pulsator valve is used. The opening area is the end face of the plunger 10, and the catching area is the difference between the end areas of the spool 11 and the plunger 10 at a certain support pressure in the drain line 13. The design feature is the use of the inertial force of the variable mass 12 fixed on the shank of the spool 11. The force occurs at the moment opening of the main distribution element.

4. Conclusions

As a result of the analysis of the known methods and drives of soil probing installations, it can be concluded that there is a very large number of them. Therefore, it is advisable to develop soil probing units with a hydropulse drive, which will make it possible to increase the efficiency of the work performed and will be able to expand the functionality due to debugging. The substantiation of sounding on different types of soils was carried out based on their physical and mechanical parameters, which made it possible to outline the spectrum of use of the installation with a hydraulic impulse drive for soil sounding. A mathematical model of the process of soil probing using vibration installations has been developed, as well as the simplest calculation model and a number of structural schemes of hydraulic hammers with a hydraulic impulse drive for soil probing.

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НОВІТНІ ТЕНДЕНЦІЇ СТВОРЕННЯ УДАРНО-ВІБРАЦІЙНОГО ОБЛАДНАННЯ З РІЗНИМИ ТИПАМИ ПРИВОДУ ДЛЯ ЗОНДУВАННЯ ГРУНТІВ

Дослідження ґрунтів шляхом занурення конуса під впливом УЗД є одним із експрес-методів отримання інженерно-геологічної інформації про фізико-механічні властивості основи з насипних ґрунтів будівель і споруд. Яка дає змогу виявити ступінь однорідності досліджуваних ґрунтів; визначити положення меж (контактів) різних літологічних шарів і несучих шарів для паливної основи; виявляти та окреслювати в плані та глибині ослаблені зони на досліджуваних ділянках для точної прив'язки місця проведення дослідних робіт; вибрати оптимальні варіанти вибору молотків; оцінювати фізико-механічні властивості піщаних ґрунтів (щільність, кут внутрішнього тертя тощо); орієнтовно оцінити модуль деформації піщаних ґрунтів.

Основними завданнями є розробка, дослідження та розрахунок основних параметрів установок з гідроімпульсним приводом для зондування ґрунтів.

Об'єктом дослідження є процес зондування ґрунту. Предметом дослідження є гідроімпульсний привід установки зондування ґрунту. Досвід показав, що ефективне використання польових методів можливе лише за умови методично правильного підходу до складання та виконання програм усього комплексу пошукових робіт.

Різноманітні аспекти проблеми комплексного дослідження ґрунтів польовими методами розроблялися поступово. Основними методами дослідження є аналіз інформації про існуючі способи та установки для напилення, математичне моделювання процесів у обладнанні установки для напилення. металевих порошків з урахуванням його конструктивних особливостей та режимів роботи на основі нелінійних диференціальних рівнянь тепловіддачі від твердих і рідких тіл з використанням чисельних методів їх вирішення на базі програми FlowVision.

Ключові слова: *комплекс, функціональність, обладнання, процес обробки, грунт.*

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