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INTERACTION OF CONICAL MONOLITHIC THIN-WALLED REINFORCED CONCRETE SHELLS WITH THE SOIL OF THE FOUNDATION AND THEIR STRESS STATE UNDER THE ACTION OF STATIC LOADING

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Abstract

The use of monolithic thin-walled spatial reinforced concrete shells as foundations for low-rise technological or residential facilities is economically feasible, in terms of reducing the volume of earthworks. Compared to classical types of foundations, it provides a significant reduction of costs of concrete, reinforcement, and labor costs. However, the issues of interaction of monolithic thin-walled spatial reinforced concrete shells with the base soil remain insufficiently researched.

The work substantiates the dynamic model of the "hammer-head-shell-soil" system when interacting with the base soil. It demonstrates that it is reasonable to use the elastic-viscous-plastic model taking into account the attached soil mass.

Based on that, the calculation scheme of this system was developed, considering the main connections between the colliding bodies and the interaction with the soil.

Taking into account the above, the mathematical model "hammer-head-shell-soil" is developed and demonstrated, which is a system of nonlinear differential equations of second order.

The solution of the system of equations gives the displacement and speed of all bodies, as well as the value of the forces acting on the contacts of colliding bodies at any moment of the time.

The presence of an oscillating process in the "hammer-head-shell-soil" system was experimentally established. The headrest oscillations are unstable.

They occur only in the event of impact and are extinguished as the load decreases. The analysis of the obtained dependencies when solving the mathematical model showed that the impact force is mainly determined by the height of the impact part and the stiffness of the elastic gasket. The ratio of the masses of the hammer and the shell has a smaller influence on the immersion process. The influence of the physical and mechanical properties of the soil base is insignificant.

Despite the periodic nature of the force impact, the shell sinks into the soil base quite smoothly.

This is explained by the significant mass of the shell, as well as the inertial stabilization properties of the soil base.

To find out the qualitative regularities and the physical essence of the process of immersion of conical blocks in natural conditions, a specially designed stand was used, which made it possible to determine the shape and dimensions of the compacted zone in different soils.

Concrete block designs of various types were developed and presented. A static load study using the "SolidWorks" program showed that concrete blocks can withstand tests for fatigue failure, for loss of stability, and have a safety margin for deformations that occur during loading. For the manufacture of concrete blocks, as the research on the material showed, it is advisable to use M300 concrete.

Introduction

Monolithic and prefabricated reinforced concrete foundations traditionally used at the moment, along with the known advantages, have great complexity of erection on the construction site, high material consumption and, accordingly, cost. The use of monolithic thin-walled spatial reinforced concrete shells (MTWCS) as foundations for low-rise technological or residential objects is economically feasible in terms of: reducing the volume of earthworks by up to 90%, saving on formwork, idle time for the concrete to gain strength. In addition, the use of MTWCS in comparison with classical types and methods of arranging foundations allows you to significantly reduce the costs of concrete, reinforcement, and labour costs, which ultimately leads to a decrease in the estimated cost of zero-cycle works by up to 40% [1, 6-8].

Statement of the problem and formation of tasks.

The issues of interaction processes of MTWCS with the foundation soil during dynamic or static immersion, as well as during building operation, remain insufficiently researched and highlighted in the scientific literature.

Immersion of MTWCS is possible by impact and static loading in the form of discrete or continuous gradual loading. Immersion by impact is a complex energy process, during which the potential energy of the hammer is transformed into the kinetic energy of the impact, which leads to the overcoming of the resistance forces of the soil base to the residual and elastic movements under the surface of the MTWCS [9, 10].

This study provides an analytical review of the methods, machines and their working bodies existing in construction practice for local form-forming compaction to intensify the process of constructing zero-cycle buildings and structures.

Justification of the type of hammer-shell interaction model.

At the same time, the impact energy developed by the falling load (hammer) is partially lost during the co-impact through the damper between the hammer and the shell, shaking the surrounding soil of the foundation, and only a part of it determines the residual movements of the MTWCS.

During the impact of the shock load, the elastic deformation of the head C_1, then the shell C_2 itself, and the soil of the base C_3 occurs, and only after that does the final vertical movement (immersion) of shell e occur. After the shock pulse is exhausted, the elastic deformations are restored. Thus, the total elastic deformation is equal to

$$C = C_1 + C_2 + C_3 . \qquad (1)$$

The values of C_1 and C_2 are usually small and can be neglected in many cases, i.e. take $C=C_3$. In the idealized schemes of changes in C and e as the impact energy of the hammer N increases, the elastic part of failure C increases at $e=0$, until it reaches the limit value C (Fig. 1). With a further increase in N, the value of C remains constant and the final failure e begins to increase. Thus, the ultimate elastic deformation of the soil C does not depend on the immersion parameters Q and H and is a characteristic of the soil.

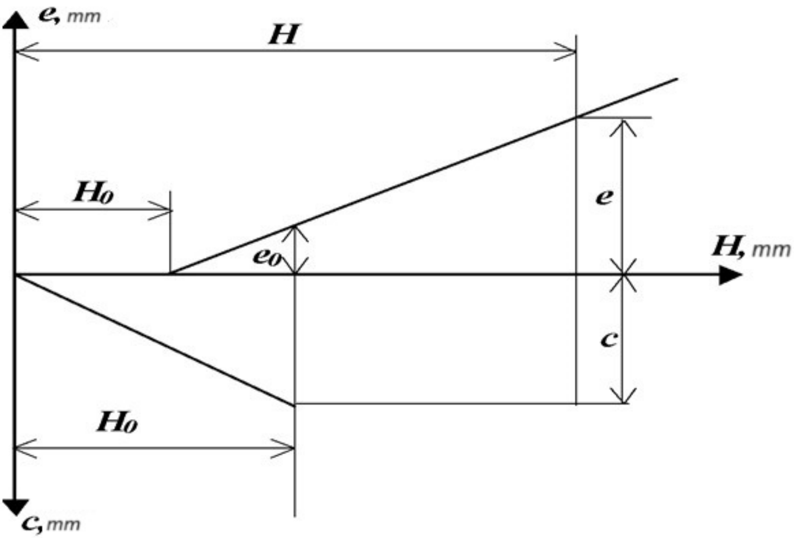


Fig. 1. Scheme of the dependence of *C* and *e* failures on the height of the fall of the hammer *H*

The dynamic nature of the load application, which qualitatively changes depending on the ratio of the three phases of the soil base, has a significant influence on the deformation and resistance of the soil to the immersion of the shells. In connection with the impossibility of taking into account all the features of the upper layers of the soil base of the building site and obtaining accurate analytical expressions of dynamic resistance, it seems appropriate to use modelling methods for this purpose. At the same time, it is proposed to apply simple models that could reflect only the main properties of the system, and a large number of temporary features would be taken into account in a generalized way or through the values of calculated indicators.

To simplify this model, the initial state of the soil and the features of its changes during deformation may not be taken into account, but only the final influence of the features of this soil on the development of resistance forces may be reflected. The simplest soil models for the analysis of the "hammer-head-shell-soil" system are plastic and elastically plastic (Fig. 2).

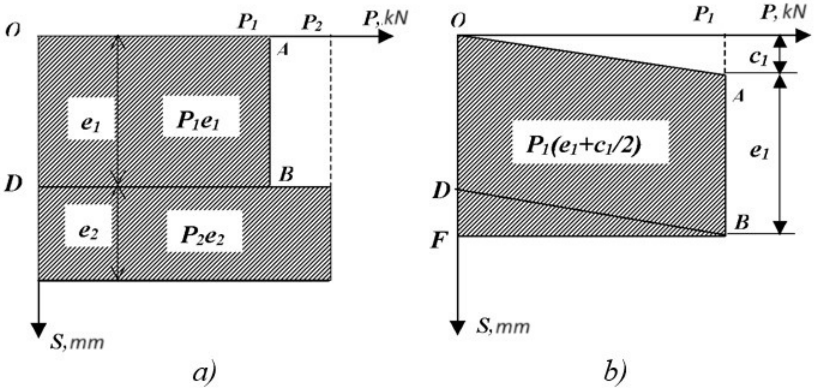


Fig. 2. Dependence between the frontal resistance to movement of the shell *P* and its settlement *S* with different models of interaction: *a* - plastic model; *b* - elastic-plastic model

The plastic model is built taking into account the following assumptions (see Fig. 2*a*). It is an absolutely solid body, and the soil surrounding it is motionless. The resistance along the side and the top is P_b, i.e. friction between the side surfaces of the shell and the ground, reduced to the equivalent Coulomb dry friction of all types (it is assumed that P_b does not depend on the speed of the shell movement). As the tests showed, bringing the dynamic side friction to the equivalent dry friction makes it possible to obtain fairly stable soil resistance values.

The frontal resistance P_l is imagined as a pinched weightless bottom. Overcoming the friction that develops on the side surface, the shell affects the bottom, which sinks if the force applied to it exceeds P_l.

The relationship between the frontal resistance to the movement of the shell and its subsidence is given in a simplified form - in the form of a broken line OAB, and it is assumed that the force P_l does not depend on the speed of the shell movement. The area of the OABD diagram represents the work for one cycle of *Pe* (see Fig. 2, *a*). Despite its simplicity, this scheme can be quite useful, as it does not require the establishment of many uncertain parameters of elasticity and viscosity.

The elastic-plastic model is distinguished by the presence of elastic ties that simulate the elasticity of the soil and intermediate elements (see Fig. 2*b*). At this stage of research, it is assumed that the elasticity of the soil is manifested mainly at the point of contact of the end of the shell with the soil. Therefore, the assumption that the lateral resistance to immersion is characterized by dry friction remains valid for the scheme.

The mechanical model of frontal resistance is simplified in the form of a bottom with a linear spring. When the casing is struck, the elastic deformation of the soil OA (compression of the spring) first occurs, and after the force in it reaches the value of the frontal resistance P_l, irreversible compression of the bottom AB begins (see Fig. 2*b*). After the load is finished, the BD is restored. This graph generally shows well the interaction of the shell with the soil.

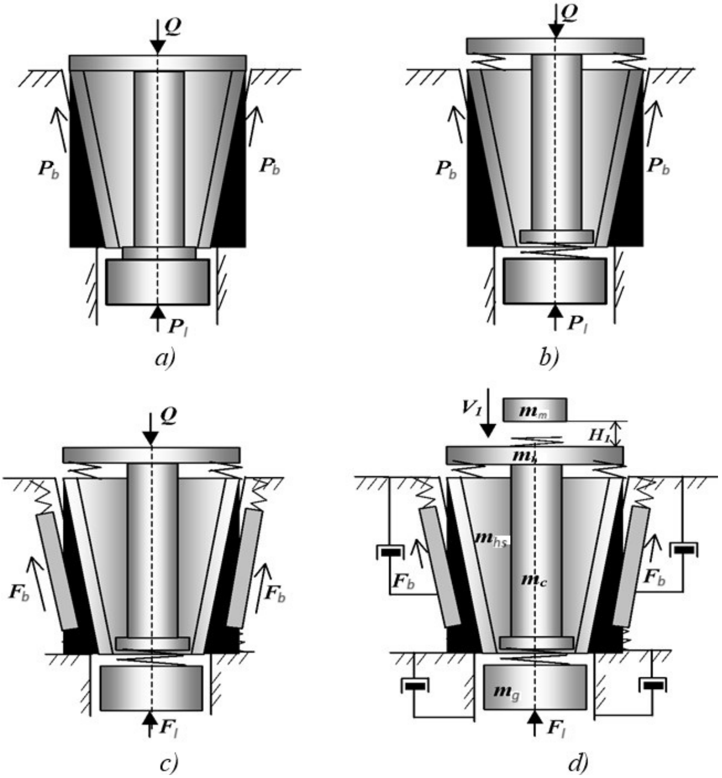


Fig. 3. Dynamic models of the "hammer-head-shell-soil" system: *a*- plastic model; *b* – elastic-plastic model; *c* – elastic-plastic model with attached soil mass; *d* – elastic-viscous-plastic model with attached soil mass

The positive properties of this model are also that when using the energy approach to determine energy costs, i.e. the area of the force-displacement diagram, the contours of this diagram, as well as the condition that C=0 do not affect the accuracy of the results.

The considered model does not take into account the influence of soil inertia, which is quite significant.

Therefore, for further clarification, an elastic-plastic model with an attached soil mass is adopted (Fig. 3*c*). In this model, the surrounding attached soil mass is represented by an equivalent elastic body resting on elastic supports. In this case, the weight of the body is equal to the weight of the attached soil.

When the shell moves after the impact, the attached mass moves together with the shell until the elastic forces of the springs reach the resistance values on the side surface P_b. After that, the shell begins to slip relative to these elements. Further interaction is similar to the interaction of the previous model.

The elastic-viscous-plastic model (Fig. 3*d*) allows you to additionally take into account the viscous resistance of the soil. Further, it is possible to clarify the nature of the change in the frontal resistance of the soil depending on the settlement during loading and unloading, i.e. apply instead of a simple Prandtl elastic-plastic model, an elastic-plastic model with compaction, etc. Thus, the number of possible variants of dynamic models can be quite large. These models will more and more fully reflect the influence of the main factors and their role in the immersion process.

In all models analyzed above, the shell is considered a completely rigid body. However, upon impact, the shell has an elastic deformation. In addition, the usual impact on the shell is performed through the elastic headband.

Therefore, the elasticity of the shell and the headrest can be represented by a spring.

Evaluating the possibility of using complex models for practical calculations, it should be pointed out that currently there is not a sufficient amount of experimental data for a reasonable assignment of the numerical values of many indicators characterizing these models. In addition, the resulting mathematical expressions of the interaction of the "hammer-shell-soil" system will become more and more complex with the complexity of the models, and this will not always contribute to increasing accuracy, i.e. practical purposes.

Considering the above, for further research it is most appropriate to use the elastic-visco-plastic model, taking into account the attached mass of the soil, the elasticity of the shell and the head (see Fig. 3*d*).

This scheme allows you to take into account the change in the value of the attached mass of the soil and the change in the interaction in connection with this.

Theoretical features of the interaction between the hammer and the shell.

Thus, the dynamic model of the "hammer-head-shell-soil" system with elastic-viscous-plastic resistance of the soil is presented as follows. The elastic shell, which is in the soil, is struck with a hard undeformed hammer through the elastic head.

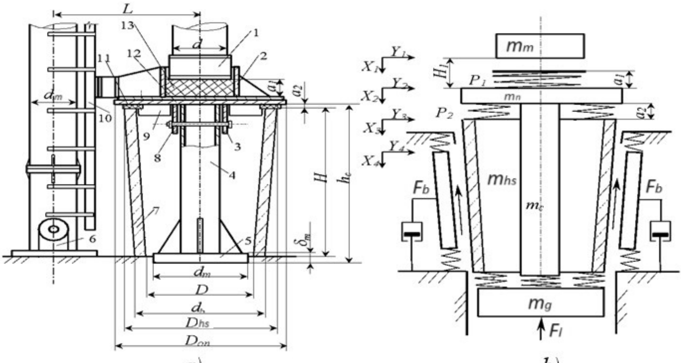
Under the influence of the impact, the shell acquires a reserve of kinetic energy, which is spent on overcoming soil resistance: with each impact, the shell sinks, initially elastically deforming the soil by the amount C, and then the plate moves in the soil by the amount of final failure e.

Elastic deformations after are restored with each hit. Each blow is considered as a single one, isolated from others, i.e. before each subsequent impact, the shell, hammer and soil are at rest.

The shock is absorbed by the reduced mass of the shell, taking into account part of the mass of the soil attached to it, and the subsequent movement is carried out only by the shell.

The hammer impact effect is represented as the transfer of some part of the kinetic energy of the impact N, which goes directly to the immersion of the shell [2-4].

For the development of a mathematical model of the process of immersion in the ground base of conical-reinforced concrete shells, a calculation scheme is proposed (Fig. 4).



a) b)

Fig. 4. System "hammer-head-shell-soil": *a)* - real system; *b)* – calculation scheme: 1 - hammer; 2 - headrest; 3 - conductor; 4 - core; 5 - tamping plate; 6 - mast; 7 - shell; 8 - finger; 9 - stops; 10 - guides; 11 - gasket; 12 - transmission plate; 13 - shock absorber

The mathematical model of this process is a system of nonlinear differential equations, which consist of the equations of the "hammer-head" and "shell-soil" subsystems, which must be solved jointly.

The mathematical model "hammer-head-shell-soil" is a system of nonlinear differential equations of the second order

$$\begin{cases} m_2 d^2X_2/dt^2 = Q_2 + P_{12} - P_{23}, \\ (m_3 + m_4)d^2X_3/dt^2 = Q_3 + Q_4 + P_{23} - F_l - F_b, \quad \text{при } F_b \le R_b \\ X_3 = X_4, \\ m_1 d^2X_1/dt^2 = Q_1 - P_{12}, \\ m_3 d^2X_3/dt^2 = Q_3 + Q_4 + P_{23} - F_l - F_b, \\ m_4 d^2X_4/dt^2 = Q_4 + F_b - K_b X_4, \qquad \text{при } F_b < R_b \end{cases} \tag{2}$$

where m_1, m_2, m_3, m_4 are the masses of the hammer, the head, the shell with the core, and the soil, respectively;

Q_1, Q_2, Q_3, Q_4 – respectively, the weight of the hammer, the head, the shell with the core and the soil;

P_{12}, P_{23} - respectively, the forces acting on the contacts of the bodies, which collide;

X_1, X_2, X_3, X_4 are, respectively, the coordinates of the hammer, the head, the shell and the soil;

F_l, F_b – frontal and lateral soil resistance, respectively;

R_b is the ultimate resistance of the soil on the side surface.

The solution of this system of equations gives the displacement and speed of all bodies, as well as the value of the forces acting on the contacts of colliding bodies at any moment in time.

Mathematical model (2) belongs to the class of simulation models, as it simulates in detail the process of submersion of shells by impact load. This nature of the model allows you to use it to study the process of computer immersion. In addition, the implementation of full-scale experiments on the immersion of shells is a rather expensive method that requires a lot of machine time [5, 6].

Experience shows that the most interesting for practice is the study of the influence of the following factors on the immersion process:

1 - the ultimate resistance of the shell on the soil;

2 - the ratio of the mass of the striking part to the mass of the submerged shell;

3 - the thickness of the elastic gasket in the headrest;

4 - lifting height of the impact part.

Wood or conveyor rubber can be used as cushioning material in the headrest. The stiffness of the soil depends on the value of the lateral resistance so that the elastic failure does not exceed 1 cm. This value of elastic failure is most often encountered in practice.

Calculations on a computer were carried out for a hammer with a striking part weighing 500 kg.

Mathematical planning of the experiment was used to organize calculations on a computer. The Hartley-Cohn four-factor plan [3] was adopted. In order to obtain analytical dependencies between the parameters of the studied system, a correlation analysis of the obtained data was carried out. For the analysis, regression equations of the type are applied

$$y = A + \sum_{i=1}^{n} B_i X_i; \tag{3}$$

$$y = A + \sum_{i=1}^{n} (B_i X_i + C_i X_i^2); \tag{4}$$

$$y = A \mathop{\Pi}_{i=1}^{n} X_i^B \tag{5}$$

Co-impacts in the "hammer-head-shell-soil" system are characterized by forces arising at the contacts of the elements that are in direct contact during the impact. In Fig. 5.*a,b,c*, the graphs of the change in time of these forces, calculated with the same initial data for a time interval equal to 0,03 s after the first contact of the hammer with the head, are given. The impulse of impact forces is characterized by several peaks and has a complex damping character. The contact of the shock part with the head is irregular. Thus, for a period of 0,06 s, 11 collisions occurred at the "hammer-headpiece" contact, and 10 at the "headpiece-shell" contact.

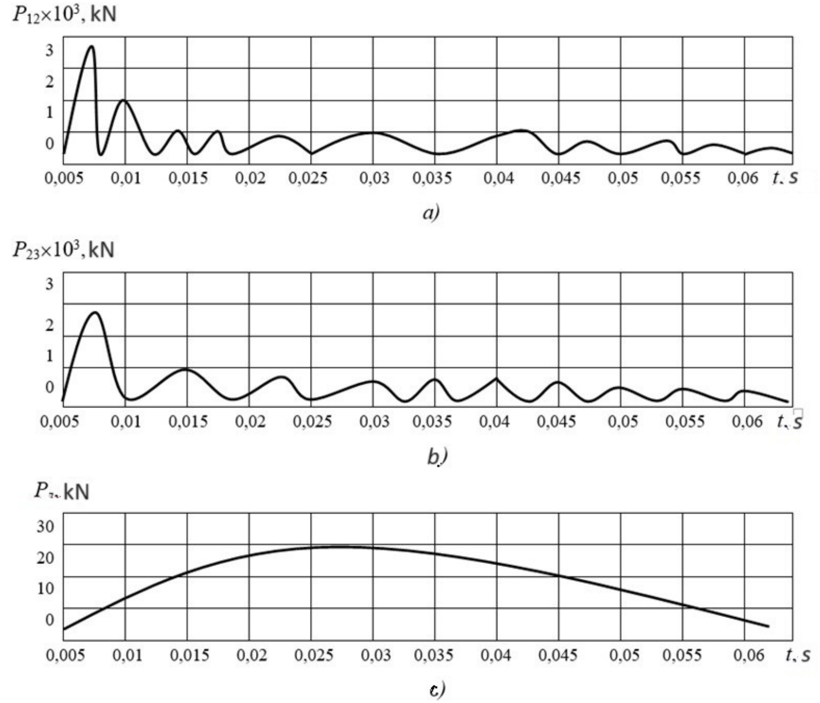


Fig. 5. Forces acting on the contacts of colliding bodies: *a* – hammer-head; *b* – a head-shell; *c* - is the frontal resistance of the soil

In this way, we can talk about the existence of an oscillatory process in the "hammer-head-shell-shell-soil" system. Oscillations of the headrest are unstable. This follows from the fact that during slow, quasi-static immersion, oscillations do not occur, they occur only during impact and die out as the load decreases.

In real conditions, due to the inevitable eccentricities of load application, the headrest carries out not only forward movement along the vertical axis but also angular oscillations. In the mathematical model, following the accepted assumptions, all movements occur only along the vertical axis, so the graph of the impact force on the shell is divided into several separate co-impacts.

The observed multiple collisions of the headpiece with the shell are due to a significantly shorter period of the headpiece's own oscillations compared to the duration of the force impact. Therefore, the headpiece can be represented as a mechanical oscillator, brought out of equilibrium by mechanical collision with the striking part, and then oscillating between two massive bodies: the striking part and the shell.

The regularities noted above were reflected in the correlation dependences for the impact force. The impact force on the "hammer-headset" and "headset-shell" contacts can be determined by the following dependencies

$$P_1 = 314 m_M H_1 + 0{,}7R + 212\frac{m_M}{m_H} + 6131\frac{a_1}{S_1} + 950, \tag{6}$$

$$P_2 = 245 m_M H_1 + 0{,}97R + 522\frac{m_M}{m_c + m_{hs}} + 9231\frac{a_2}{S_2} + 637, \tag{7}$$

where m_M, m_H, m_{hs}, m_c - respectively, the mass of the hammer, head, shell, and core;

a_1, S_1, and a_2, S_2 – respectively, the thickness and area of the cushioning pads at the "hammer-headrest" and "headrest-shell" contacts;

H_1 - hammer lift height;

R - soil resistance.

The correlation ratio of these formulas is at least 0,95. This testifies to the correct selection of varied parameters.

The analysis of the given dependencies shows that the force of the impact is mainly determined by the height of the impact part and the stiffness of the elastic gasket. The ratio of the masses of the hammer and the shell has a smaller influence on the immersion process. The influence of the physical and mechanical properties of the soil base is insignificant.

Despite the periodic nature of the force impact, the shell sinks into the soil base quite smoothly. This is explained by the significant mass of the shell, as well as the inertial stabilization properties of the soil base. The shell receives a positive acceleration under the influence of the first co-impact, then the shell acceleration changes its sign, i.e. the shell's movement slows down.

For the value of the final failure, the best result is given by the dependence of the form:

$$e = 1{,}2\frac{m_{м}H_1\left(\dfrac{m_{м}}{m_{н} + m_c + m_{hs}}\right)^{0,2}}{R^{1,3}\left(10a_1\right)^{0,64}} . \qquad (8)$$

Analysis of the influence of various factors on the size of the failure shows that the impact of the stiffness of the shock absorber can be neglected, since the reduction in failure when the thickness of the lining increases from 0,05m to 0,25m does not exceed 10%. Therefore, for practical purposes, dependence (8) can be simplified

$$e =,2\frac{m_{м}H_1\left(\dfrac{m_{н}}{m_{н} + m_c + m_{hs}}\right)^{0,2}}{R^{1,3}} . \qquad (9)$$

Experimental part and modeling in Solid Works.

The study of the process of immersing conical blocks in the soil Fig. 6, was carried out in the immediate vicinity of erected houses and structures on construction sites in places that are characteristic from the point of view of the geological structure and the main characteristics of the soil, located within the boundaries of the construction site. A specially developed stand [3, 5] was used to clarify the qualitative regularities and physical essence of the process of submersion of conical blocks in natural conditions.

The research stand (Fig. 7) consists of: anchor piles 1, reinforced concrete blocks 2, transverse beams 3, fittings 4 and clamps 7 connecting anchor piles with transverse beams. Clamps 5, which hold the transverse beam 8 with mounting brackets 6 in a fixed position, the tested block 9 with a supporting bridge 10, a support plate 11, a hydraulic jack 12 with a load capacity of up to 500 t with a rod 13, concrete slabs 14 for transferring the load to the transverse thrust beam 8, pumping unit 15, shock absorber 16 and wells 17, which provide the possibility of soaking the soil to a depth of 5 m and a metal insert 18 for distributing the load over the volume of the shell.

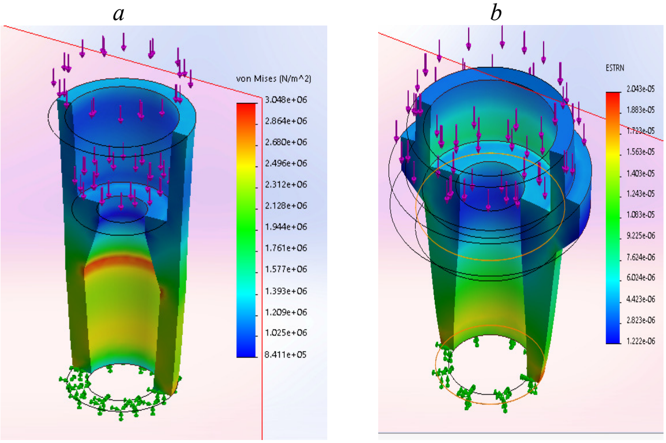


Fig. 6. Conical concrete blocks of various types for erecting foundations for buildings: *a* - conical block for columns of frame buildings; *b* - conical block with an extended upper part

During experiments in type II soils, soil soaking was carried out. For this, boreholes with a diameter of 200 mm and a depth that is 2 times greater than the height of the stamp were drilled around the block in a radius of 2 m with a step of 2 m. The sequence of the experiment includes the following:

1. The main physical and mechanical properties of the soil are determined with the help of the Lytvynov field laboratory (PLL-9).

2. The soil is soaked using pre-drilled wells to a depth that is 2 times greater than the height of the stamp.

3. A submersible stamp is installed on the design mark, on the upper section of which a transfer plate with a hydraulic jack is mounted.

4. The jack is turned on, the force of which is transmitted through the rod and the support beam to the upper section of the block, through the base plate and through the metal insert on the bridge, which allows unloading the upper part of the block, as a result, the stamp sinks into the soil by the stroke of the rod equal to 200 mm.

5. The hydraulic jack rod returns to its original position. A concrete slab with a thickness equal to the working stroke of the hydraulic jack rod of 200 mm is placed under the base plate, then the working fluid is fed into the piston cavity and the next stage of immersion takes place.

6. Immersion is carried out to a depth at which the deformation of the soil stabilizes in the longitudinal and vertical directions, while a compacted zone with areas of different densities and shapes is formed.

7. After sinking to the design mark with the help of a crane, the block is pulled out of the soil and the dimensions and physical and mechanical properties of the compacted zone are determined in the pit.

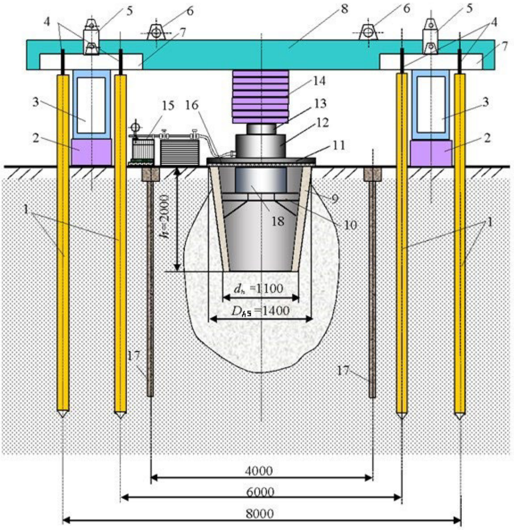


Fig. 7. Structural diagram of the stand for studying the immersion process

The resistance of the soil during the immersion of concrete blocks is determined by the degree of its compaction, the dimensions of the compacted zone, the strength and deformation characteristics of the soil.

As a result of the experiments carried out in the conditions of various construction sites, the study of the density of forest-like and clayey soils, it was established that with an area of the lower base equal to 0,2-0,3 m^2 (Fig. 8), the compacted zone extends to the clay – 0,8 m from the lower section of the block.

In terms of its shape, the compacted zone in various soils approaches an ellipsoid of rotation (Fig. 8), the major axis of which coincides with the vertical axis of the block. At the same time, a significant part of the compacted zone is formed under the base of the block. This is one of the differences in the formation of a compacted zone in comparison with piles, which have a much smaller area of the lower base. When submerging blocks whose area is close to 0,2-0,3 m^2 (Fig. 8, *a, b*), the compacted zone is characterized by the presence of four areas with different densities: the area with the highest density in the form of an elongated ellipsoid of rotation in the horizontal plane with a density of about 2 g/cm^3 (cork). Below the cork is an area with a density of 1,9 g/cm^3 (core), it is located directly under the base of the element that is immersed, and is close in shape to a sphere, the diameter of which is approximately equal to: d_j =1,1d_b, where d_b is the diameter the basics of the block. A compacted core with a density equal to 1,9 g/cm^3 for loams and sandy loams is adjacent to a region with a lower density, approximately 1,8 g/cm^3. Next, the area with a density of about 1,7 g/cm^3, while the density of the soil of natural composition can be equal to 1,6-1,5 g/cm^3.

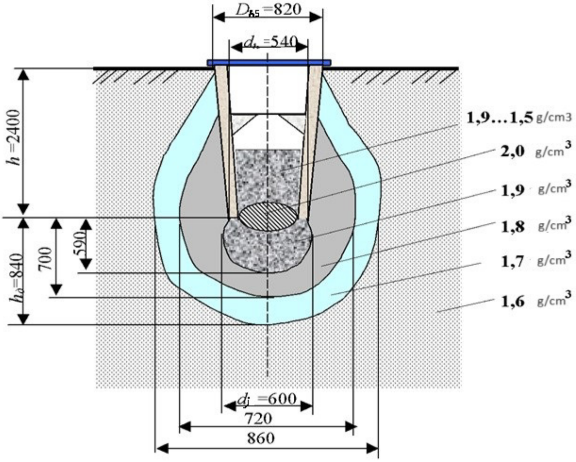


Fig. 8. The formation of a compacted zone during the immersion of conical concrete blocks with a base area of 0,2-.0,3 m^2 in forest-like and clayey soils

Immersion of concrete blocks can be carried out both by shock and static load. At this stage, preference is given to machines that perform immersion by the compression method. At the same time, the force developed by this machine is in the range of 100...120 t and more.

The graphs of the stress state of various concrete blocks under the action of static load are presented below. The plots were built using the SolidWorks computer program [14-17]. The initial data, in this case, were the following parameters: geometric dimensions of the block, wall thickness, material (concrete M300) and static load of 60 tons.

It should be noted that the study of the stress state was carried out at the moment of the greatest soil resistance on the side and front surfaces of the block. This condition can be observed when the block is completely immersed in the soil base. At this moment, the stress in the material reaches its maximum value.

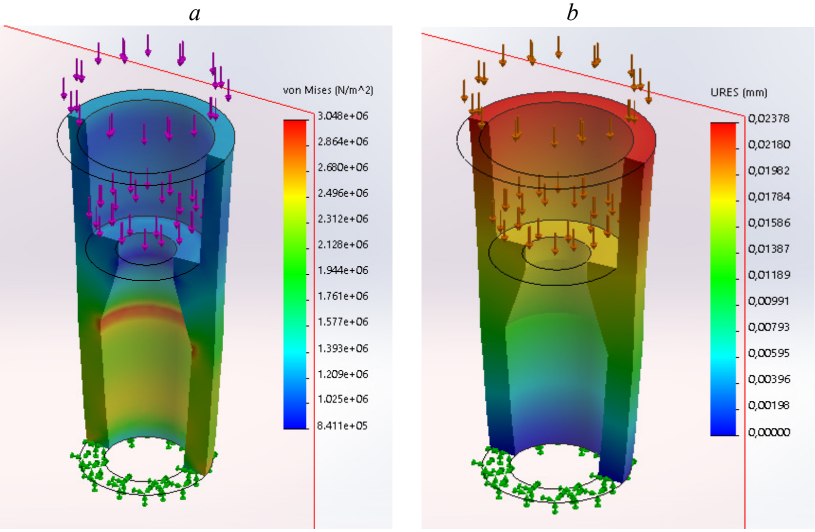


Fig. 9. Plots of stresses *a* - and displacement *b* - of a conical block under the columns of frame buildings.

The stress diagram (Fig. 9*a*) allows you to plot the resulting stress in different places of the structure under static and dynamic loads according to the Mises criterion. It can be seen from the plot that the greatest stress according to this criterion occurs in the middle part of the conical block at the end of the internal structural element. Closer to the upper section of the shell, the stress decreases, towards the lower supported ring it will also be smaller.

In fig. (Fig. 9*b*) shows the diagram of movements, which characterizes the stability of the block under loads, provides the possibility of obtaining the results of the movement and researching the structure for loss of stability. It can be seen from the displacement graph that the most significant displacements during loading will occur in the upper and middle parts of the block.

A concrete block (Fig. 10) with an expanded upper part has a higher bearing capacity. In addition to the formation of a compacted zone under its base and support on the side surface, it rests on the soil with its upper, wider part, which increases its bearing capacity by approximately 10-15%.

a *b*

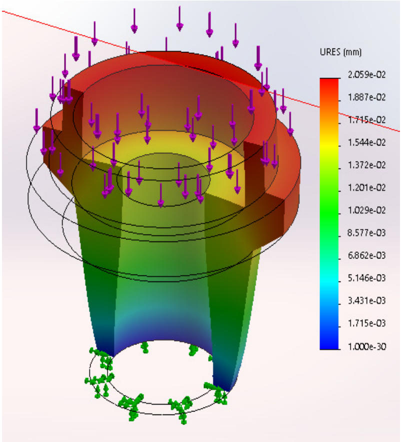


Fig. 10. Plots of stresses *a* - and displacement *b* - of a conical block with an extended upper part under the columns of frame buildings

It can be seen from the stress plot (Fig. 10*a*) that the greatest stress will be at the base of the conical shell. Closer to the upper section of the shell, the stress decreases [11-13].

In fig. (Fig. 10*b*) shows the diagram of movements, which characterizes the stability of the shell under loads, and provides the possibility of obtaining the results of the movement and researching the structure for loss of stability. It can be seen from the displacement graph that the most significant displacements under loads will occur in the upper part of the conical block. In the lower part, they will be minimal.

Conclusions

1. The proposed dynamic model and calculation scheme of the "hammer-head-shell-soil" system with elastic-viscous-plastic resistance with attached soil mass.
2. The mathematical model of the researched process is formed, which is a system of nonlinear differential equations, which consists of the equations of the "hammer-head" and "shell-soil" subsystems, which must be solved jointly.
3. Determined dependences for the impact force on the "hammer-headrest" and "headrest-shell" contacts.
4. To clarify the qualitative regularities and the physical essence of the process of immersion of conical blocks in natural conditions, a specially designed stand is proposed and research methods are presented.
5. As a result of the experiments carried out in the conditions of various construction sites in forest-like and clayey soils, the dimensions, shape and density of the soil core formed under the base of the shells were determined.
6. The study of the stress state of concrete blocks of various types using the SolidWorks program showed that their construction withstands tests for fatigue failure, loss of stability, margin of strength, and deformations that occur under load.

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