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MACHINES AND EQUIPMENT FOR THE ARRANGEMENT OF RECESS FOR FOUNDATIONS OF QUICKLY INSTALLED TECHNOLOGICAL MINING FACILITIES WITHOUT DIGGING

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Annotation.
In construction practice, for the construction of foundations without excavation and formwork, the methods of ramming and stamping of the soil base can be successfully used. Under ramming means the formation of a depression by directional dropping from a certain height of the rammer, which has the shape of a future depression, and under stamping, the formation of a depression by driving a template stamp to the required depth and then removing it from the ground. The resulting recess is filled with concrete directly or a prefabricated element is installed in it. The use of these methods makes it possible to reduce (by 3...6 times) the volume of earthworks in comparison with the traditional methods of construction of foundation pits. The presence of a compacted zone at the base and around the sidewalls of the recess can significantly reduce the size of the foundations and reduce the consumption of concrete by 1,2...2 times, and reinforcement - by 1,4...4 times. To increase the bearing capacity of the upper soil layers and in order to eliminate the effect of frost heaving of the soil into the walls and bottom of the deepening, waste from the mine, mining and processing industry is rammed in separate portions in the form of crushed stone, sand and gravel mixture, coarse sand, screening and other materials. The energy and number of strokes of the stamp are determined by the required depth of the deepening and the type of soil.

The questions of the rational shape and size of dies, technical and technological parameters of machines and equipment for the installation of recesses for the foundations of rapidly erected technological mine structures, taking into account the technogenic local soil bases and "waste" rocks, remain open.

Below is a description and analysis of methods for constructing recesses for foundations without excavation, the results of research and the creation of highly efficient working equipment are given. Recommendations are given on the choice of the parameters of the working equipment for the formation of depressions in the base with a seal.

Problem statement and task formation.

The technological complexes of mines and metallurgical enterprises in various combinations include buildings: heating installations, ventilation installations, electrical substations, crushing and screening complex, compressor installations, repair, electromechanical workshops, workshops, etc. [1].

Among them, one can conditionally distinguish:

- the main buildings and structures that are directly related to the technology of mining and distribution of minerals;
- auxiliary - not directly involved in the technological scheme of the movement of fossils. As a rule, these are one-story fast-assembly buildings.

One of the possible ways to improve the process of setting up foundations for mine objects is the use of the processes of stamping, ramming-out trenches, pits, various deepenings for free-standing foundations, for example, under the shop columns, as well as the implementation of thin-walled spatial reinforced concrete foundation shells into the upper layers of the soil. [2-5].

Not sufficiently studied, at this stage, are the processes of ramming and stamping of technogenic soil bases with significant inclusions of minerals themselves, as well as "waste" rock.

This study provides an analytical review of methods, machines and their working bodies existing in construction practice for local shaping compaction in order to intensify the process of erecting the zero cycle of the above-mentioned buildings and structures.

Methods for constructing recesses for foundations and equipment used

Installation of foundations in rammed recesses.

The foundations that compact the soil include driven prismatic, pyramidal piles; downtrodden blocks; rammed piles in drilled holes; vibro-stamped piles, etc. The most promising for rapidly erected technological buildings and structures of mine facilities are foundations in rammed or stamped depressions [6-10]. The device of recesses is carried out after the planning of the built-up area by cutting or adding soil from the level of the base of the floor. The ramming of the depressions is carried out by a rammer falling from a height of 4-8 m along a guide bar, which has the shape of a future foundation and a mass of 1,5-7 tons, stamping of depressions for small sizes of

foundations and loads on them is carried out by driving a ram-template with its subsequent extraction [11-14].

After ramming or stamping, monolithic concrete is poured into the recess (without formwork) or a prefabricated foundation is installed, which has a shape and size close to the recess. The load from the foundations in rammed depressions is transferred to the soil of the compacted zone (Fig.1), thereby reducing the deformation of the soil from the load of the foundations, and the settlement of foundations from the load when the soil is soaked usually does not exceed 2-6 cm. The settlement of the foundation in the depressions can be significantly reduced (1,5-3 times) by means of a broadened base (see Fig.1*б*).

To create a widened base, hard material is rammed into the bottom of the finished pit with the same rammer: technological "empty" detrital rock, crushed stone, gravel, coarse sand, hard concrete, etc. This operation is performed, as a rule, immediately after ramming of the recess without changing the position of the mechanism and the guide rod.

Ramping of hard material into the bottom of the recess is carried out by dropping the rammer from a height of 4-8 m. When the soil falls from the walls of the pit, the height of the ramming is reduced to 3-4 m.

An increase in the bearing capacity of foundations in rammed recesses is achieved by increasing the depth, as well as by arranging an expanded zone in the lower and upper parts of the foundation. Depending on the method of increasing the bearing capacity, foundations in rammed and stamped depressions are divided into the following: without a broadened base with a flat (see Fig.1*а*) or pointed sole, performed without ramming hard soil material into the bottom of the completed recess; with a widened base, obtained by ramming into the lower part of the deepening with separate portions of soil material "waste" rock, crushed stone, gravel, sand and gravel mixture, slag, coarse sand, etc. (see Fig.1*б*); with a bearing a layer created by the formation of several depressions (two to four), filled with a rigid soil material, with its compaction with the same rammer and the subsequent formation of another recess between them for a foundation with a widened base (see Fig.1*в*).

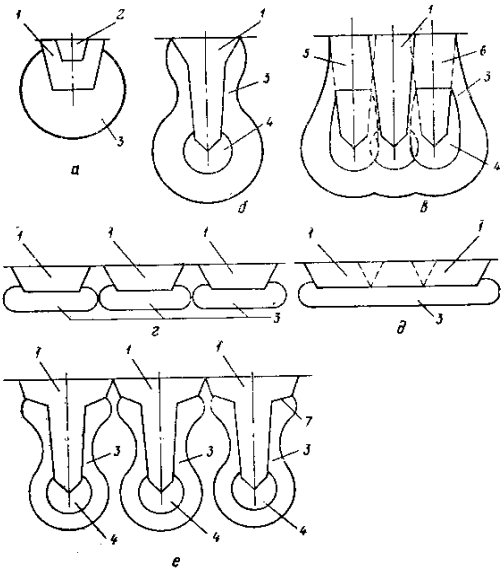

Fig. 1. Types of foundations in rammed recesses: *а* - without a broadened base; *б* - with a broadened base; *в* - with a bearing layer; г - tape intermittent; *д* - solid tape; *е* - tape arched; *1* - foundation; *2* - glass for installing the column; *3* - compacted area; *4* - rammed hard material; *5,6* - pits to create a broadened base; *7* - consoles of soil from the walls of the pit, the height of the rammer dropping is reduced to 3-4 m

According to their relative position and the nature of their interaction with the ground, foundations are divided into the following: stand-alone (columnar), which do not affect each other both during the formation of a depression and during the transfer of the payload from buildings to the ground; intermittent tape (see Fig.1*г*), arranged in depressions closely spaced from each other, taking into account the mutual influence of neighboring foundations during the formation of a recess and during the operation of foundations with base soils; continuous tape (see Fig.1*д*), made with overlapping ramming traces; continuous arched (see Fig.1*е*), made by ramming with consoles-slats in the upper part.

Equipment for ramming recesses. The ramming of the recesses is carried out using attachments, consisting of a rammer, a guide rod or frame, which ensure that the rammer falls exactly in the same place, and a carriage, with which the rammer slides along the guide rod.

Attachments are attached to a crane excavator or tractor. When forming small-sized recesses in the plan, piling equipment can be used.

For lifting and dropping the rammer, a hoisting mechanism winch is used; when using a pile driving unit, a template stamp is driven into the ground with a pile driving hammer.

The most convenient and productive attachments are attached to the excavator-crane, which has a friction winch and in this regard, provides lifting and dumping of the rammer. In this case, the type of excavator-crane is selected taking into account that its carrying capacity is 2,5-4 times greater than the mass of the rammer. When this condition is met, the normal operation of the excavator-crane is ensured during the movement and ramming of the depressions and its wear is practically excluded.

Equipment based on a crane excavator. Attachments to the excavator-crane can be of two types: with a hinged guide rod to the crane boom (Fig.2*а*), providing work with a rammer weighing 3-6 tons, and hinged fastening of the guide frame to the shovel boom (see Fig.2*б*) for rammers weighing 6-10 tons.

The guide frame (see Fig.2*б*) consists of a guide post with a length of 10-15 m and a spacer that increases the rigidity of the attachment and limits the boom reach, which improves maneuverability and more fully utilizes the lifting capacity of the excavator-crane.

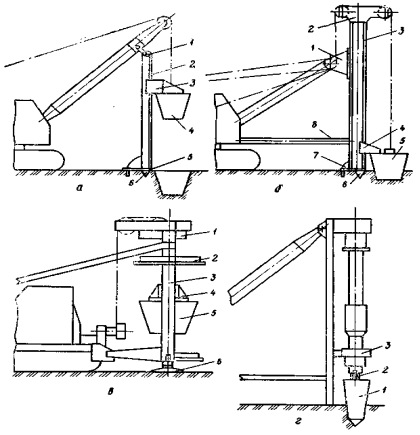

Fig. 2 - Equipment for ramming recesses:

а - on the basis of an excavator with a dragline boom: *1* - hinge; *2* - guide rod; *3* - carriage; *4* - rammer; *5* - base plate; *6* - teeth;

б - on the basis of an excavator with a straight shovel: 1 - earring; *2* - head; *3* - guide post; *4* - carriage; *5* - rammers; *6* - teeth; *7* - base plate; *8* - spacer.

в - on the basis of the tractor: *1* - head; *2* - stiffening element; *3* - guide frame; *4* - carriage; *5* - rammer; *6* - base plate;

г - on the basis of piling equipment: *1* - ramming template; *2* - suspension; *3* - hammer

The rammer (Fig. 3) is made of a metal sheet 10-16 mm thick by welding individual elements at the joints. On top of the rammer has a cover made of a sheet 20-30 mm thick with bolts with a diameter of 30-60 mm, with which the carriage is attached to it. The inner part of the rammer is filled with concrete to a height at which its specified mass is provided.

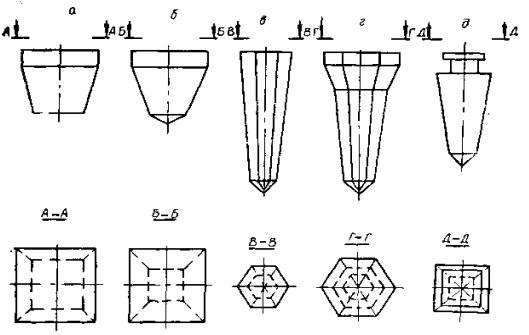

Fig. 3. The main types of rammers for ramming recesses: *а* - with a flat sole; *б* - with a pointed sole; *в* - elongated for the construction of foundations with a widened base; *г* - the same, with a broadened upper part; *д* - for ramming using pile driving equipment

Tractor-based equipment. Attachments based on tractors provide the ability to work with rammers weighing 2,5-3 tons and consists (see Fig.2*в*) of a guide frame attached to the rear of the tractor; block systems; pendants; counterweight installed at the front.

Equipment based on a pile driving unit. When using a pile driving unit for punching depressions, a hollow metal stamp-template is used as a working body, rigidly fixed with bolts on a hammer (see Fig.2*г*) or attached to it using rope suspensions. Maximum stamp size at the top in width when using tubular diesel hammers should be no more than 1 m, and rod - 0,9 m. The immersion depth is 1,5-2,5 m.

Crane-based attachments. The equipment is hung on a crane boom with an articulated guide bar suspension. Crawler cranes and pneumatic-wheeled cranes are usually used to ram the recesses. The guide bar to the crane is usually the same design as the bar to the lattice boom excavator.

A review of the methods for the formation of depressions by soil compaction and the equipment used in this case shows that when

ramming depressions for foundations without a broadened base, rammers are used with a height of 1-2 m, 0,7-1,8 m at the top, 0,4-1,4 m at the bottom, and for foundations with a broadened base - a height of 1,5-3,5 m, a size at the top of 0,6-1,2 m, at the bottom of 0,4-1 m with a pointed angle of 60-90° the lower end, often with broadening in the upper part.

When stamping recesses, a template is used with a size in the upper part of 0,9-1 m at a depth of immersion of 1,5-2,5 m. The choice of methods and type of working equipment is mainly determined by the size of the recess, soil conditions and dynamic impacts on closely located buildings and structures.

Analysis of scientific and technical solutions in the field of improving equipment for the formation of recesses in the ground.

Analysis of scientific and technical information, inventions and patents allows us to speak about the variety of design solutions for working equipment and working bodies aimed at ensuring the effectiveness of the formation of depressions by soil compaction. This problem is solved in various ways, for example, by reducing the breakout force of the working body, increasing the duration of the shock pulse, increasing the specific shock load, increasing the reliability of the gripper, using special and universal working bodies.

Installation for ramming individual recesses (Pat. № 1098996). The device is mounted on a base vehicle - a single-axle tractor (Fig.4*a*) with a semitrailer chassis, on which a guide mast 4 and a pivot frame 6 are pivotally attached, connected to the chassis by means of a power cylinder 1. By means of a device 5, mount mounted on the swing frame, it is quickly connected to the guide mast. In addition, the guide mast is equipped with a lock 7 for attaching the tamper lifting mechanism 2 to the rope 3 during the installation of the device in the working position and transportation. The latch 10 ensures reliable fastening of the guide mast to the chassis during transportation of the device.

At the place of work, the device is transferred from the transport position (dash-dot image) to the working one. To do this, the fixator 10 is removed from the corresponding hole in the chassis, after which, by turning on the tamper lifting mechanism, the guide mast is lifted until it takes a vertical position. With the help of the device 5,

the guide mast is attached to the rotary frame 6. The fixator 7 is disconnected from the rope and a rammer, movably installed on the guide mast, is suspended from the latter. By switching on the power cylinder 1, they provide precise guidance of the rammer. After that, with the help of the power cylinders 8, the load taken by the guide mast through the base plate 9 is transferred to the ground.

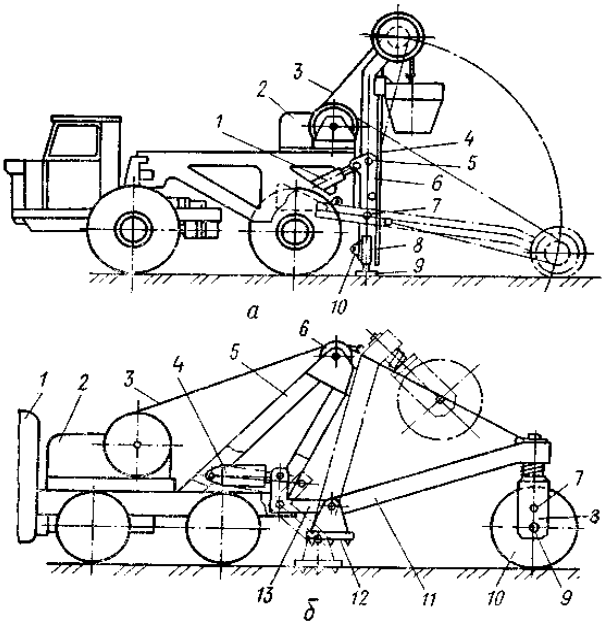

Fig. 4. Installations for ramming: *а* - separate recesses; *б* - continuous recesses

Installation for ramming linear-extended and continuous recesses (Pat. № 1151643). On the base machine 1 (Fig.4*б*), the mast 11 is mounted, connected to a stamp 10. To change the tilt of the mast, to set it in the working or transport position, on the base machine there is a mechanism 2. The rammer is installed on the axis 9 P-shaped traverse 8, in the upper part of which there is a ball joint with a pivot (not shown in the figure), connected to the mast. The traverse 8 is equipped with fixing elements 7 to prevent the rammer from turning during operation, removable during transportation. The lifting and dropping of the tram is carried out with the help of the traction rope 3, passing through the branch block 6 located in the upper part of the

bracket 5. The mast, connected by the traction rope with the mechanism 2, is installed on the support platform 12, which is connected to those mounted on the base machine with two-arm levers 13, equipped with a swing drive, for example, hydraulic power cylinders 4.

With the help of mechanism 2, the mast with a rammer is lifted to the extreme upper position and dropped into the place of ramming to formthe recess for the foundation accurately. To move the installation to a new place of work, the support platform 12 and the rammer are raised above the ground.

When ramming depressions for tape foundations, to eliminate at the bottom of the deepening of the soil ridges between the ramming zones, the rammer is lowered into the depression (with the support platform raised) and by moving the installation along the tape foundation, these ridges are removed, using the ram as a static roller

In the same way, the unit can compact the bottom of trenches which were made without it.

Working element for ramming continuous cantilever recesses (Pat. No. 817137).

The device consists of a rammer 1 (Fig.5*а*) with hollow cantilever elements 2, symmetrically located relative to the vertical axis, having the shape of semi-arches and a radially decreasing cross-section. The device has guides made in the form of racks 3 and blocks 4 for a hoisting rope. The mass of the rammer is 15-20 times the weight of the cantilever elements. The device allows you to obtain a continuous recess of the arched shape.

Working body for ramming continuous recesses with an inertial element (Pat. № 1067140). The device consists of a rammer 5 (see Fig.5*б*) and an inertial element 3, which through an adapter 4 is rigidly attached to the upper end of the rammer coaxially with it. Guide rails 1 and devices 2 for connection with a vertical movement drive are mounted on an inertial element, the mass of which exceeds 15-20 times the mass of the rammer connected to it. The hollow rammer is made in the form of an elongated trapezoidal prism with a side slope of 1:10-1:20 and a large base upward. The ratio of the rammer width to its height in the middle of its height is not less than 0,7, and to the length is in the range of 0,15-0,2.

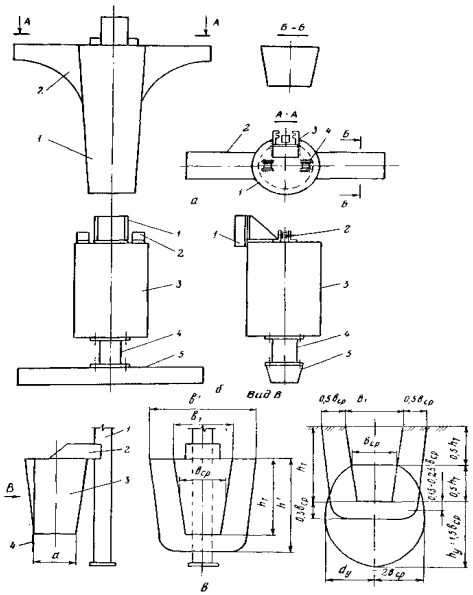

Fig. 5. Devices for ramming continuous recesses: *а* - with cantilever elements; *б* - with an inertial element; *в* - with a flat element

The adapter 4 serves to increase the depth of ramming of a continuous recess or trench and has a tubular or box-shaped section, the diameter or width of which is less than the width of the upper end of the rammer.

After installing the device in its original position using a vertical movement drive (not shown in the figure), the rammer is periodically raised to the design height and dropped along the guides. In this case, continuous grooves or trenches are rammed in such a way that half the distance between adjacent ramming points (positions of the device's center of gravity) is 5...10 cm less than the distance in plan from the ramming center to its edges.

Working body for ramming continuous recesses with a flat element (Pat. № 1153006). The device consists (see Fig.5*в*) of a guide rod 1, a carriage 2 and a rammer 3 with a flat element 4. When ramming, the guide rod is installed, the ram is lifted and dropped until a deepening of the design depth is obtained. For ramming a continuous recess, the guide rod 1 is moved by the value of the

ramming step and the lifting and dropping of the rammer is repeated, while the first element which is immersed in the soil is flat element 4, which fixes the direction of movement of the lower part of the rammer 3 and limits the movement of the compacted soil to rammed recess. A flat element has a width $b=h+h_{cp}/2$. The device makes it possible to obtain both a separate and a continuous recess, which has a rectangular shape in the vertical plane.

Working element for ramming recesses with moulded casings (Pat. № 1046463). The device (Fig.6*a*) is installed on the base machine (not shown in the figure) with a vertical guide bar 6, a step rammer 5 is connected to the guide bar with the possibility of free movement and interaction with the stop resting on the ground. The stop consists of several hollow casings 1,2 nested one inside the other.

The hollow casing in vertical section has the shape of an inverted truncated cone, and in plan it can be round, square, rectangular, etc. Each casing is equipped with rigid supporting elements 4.

The rammer consists of several staggered sections. The shape of each section corresponds to the internal dimensions of the casing interacting with it.

Along the axis of the future foundation, hollow casings 1,2,3 are installed one into the other and they begin to ram the recess. After immersion in the ground of the first casing 3, its upper support element abuts against the lower element of the casing 2, and then both casings are immersed simultaneously. Then the next casing 1 is connected in the same way. The recess is concreted in parts. Having laid the first portion of concrete 8, they begin to remove the lower casing, applying a dynamic (vibration) and upward static load to it at the same time. Extraction is carried out, for example, using a vibration gripper 7, the ends of which are inserted into special grooves of the upper supporting element 4 of the removable casing. The vertical force P is created by any lifting mechanism. The following sections are concreted in the same way.

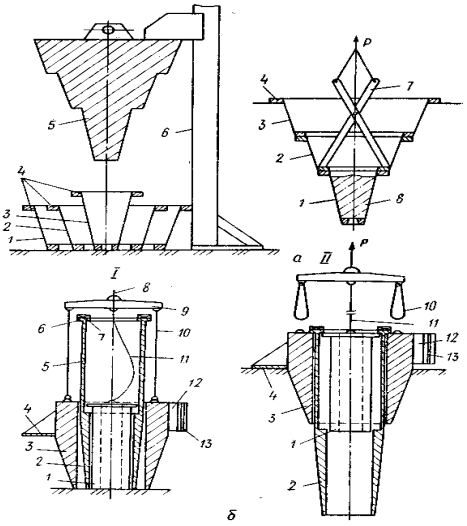

Fig. 6. Devices for ramming recesses: *а* - with moulded casings; *б* - with multi-mass working body I - initial state; II - removal of the working body

Working element for ramming recesses with multi-mass working body (Pat. № 1090801). The working body includes a central impact mass 1 (see Fig.6*б*) with a through hole for air outlet and a flange protrusion. An eyelet is attached to the upper end of the central shock mass. Mass 1 is covered by an intermediate shock mass 2, which is made in the form of a hollow truncated cone. Mass 2 has on a large base guides 5 of cantilever flange protrusions 6, at the end sections of which stops 7 are installed on the inner side. External shock mass 3, which is made in the form of a hollow truncated pyramid with a large base directed upwards, is installed coaxially with respect to mass 2. Mass 3 is equipped with three cantilever support platforms 4 with stiffeners. The lugs and the carriage 12 with grooves 13 are attached to the shock mass 3. The gripper 9 has a traction rope 8 and slings 10, connected to the lugs by means of hooks with carabiners, as well as a flexible connection 11, which is attached to the lug of the central mass.

The working body is mounted on the guide bar of the attachment of the base hoisting machine and is attached to the traction rope 8 of the winch through the gripper 9 (the guide bar and the base hoisting

machine are not shown). The tractive effort by means of slings 10 is transmitted to the external shock mass 3 with the carriage 12, which slides with grooves 13 along the guide rod, and the inner surface of the mass 3 along the cantilever guide 5. When moving upwards, the mass 3 reaches the end of the cantilever guide 5, abuts against the flange protrusion 6 and raises the intermediate shock mass 2. When the intermediate mass abuts against the flange protrusion, the rise of the central shock mass 1 begins. The length of the flexible connection is chosen so that when the working body is lifted, traction force is not transmitted to it.

Having raised the working body to the required height above the ground level, it is dropped in a directed manner. First, the central mass 1 interacts with the soil, then the intermediate mass 2 and the outer mass 3.

A series of blows by the working body leads to the formation of a recess with a broadened upper part in the form of a truncated pyramid, while masses 1 and 2 ram the main part of the recess, and mass 3 forms a broadening. Masses 1 and 2 make up 70% of the total mass of the working body, and therefore the rate of penetration of the main part of the deepening exceeds the rate of penetration of the broadening. The maximum broadening depth is limited by the cantilever support pads 4, i.e. when the support pads begin to interact with the ground surface, further deepening of the outer mass stops.

Equipment for ramming recesses with rotary motion of inertial masses (Pat. № 742528). The working body consists of a body 2 (Fig.7*a*) with a cavity and a bottom 1 and grooves 5 for directed movement, a rod 6 with inertial masses 3 and 4 and a thrust nut, an eyelet for fastening a hoisting rope. The bar 6 and the inertial masses 3 and 4 are equipped with screw guides, made along the right and left screw lines, respectively. The masses 3 and 4 are interconnected by flexible ties, and the mass 3 has thrust protrusions 7 in the form of hemispheres.

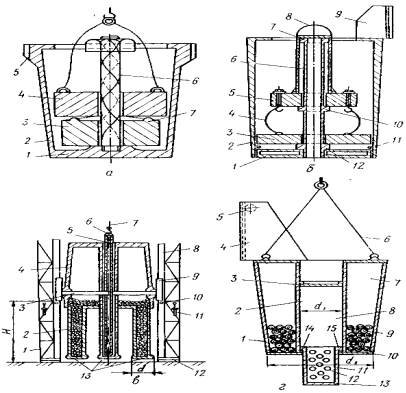

Fig. 7. Equipment for ramming recesses: *а* - with rotary motion of inertial masses; *б* - with inertial masses and a movable bottom; *в* - with shock glasses; *г* - with metal ballast

Using the winch of the base machine (not shown in the figure) by means of a rope fixed to the lugs of the inertial mass 4, the working body is raised to a certain height. When lifting, the mass 4 moves along the screw guides along the rod 6 until it rests against its top edge against the thrust nut. Mass 4 is connected to mass 3 by flexible connections, therefore, simultaneously with the rise of mass 4, the mass 3 rises, which also moves along helical guides.

Screw guides on the rod, as well as guides of inertial masses are made with a large helix rise angle equal to 70-88°, which excludes self-braking. For the perception of dynamic loads, the guides are trapezoidal. The length of flexible links is selected so as not to impede the movement of inertial masses both during the impact period and during their rise.

Having raised the working body to the required height, it is directed to the ground. During the period of free fall of the device, inertial masses are in the extreme position relative to the level of the bottom surface. Upon impact, the body with the bottom and the rod 6 rigidly connected to them are decelerated. However, under the action of inertial forces, the masses 3 and 4 continue to move downward in the direction of the impact, interact with the rod and thereby lengthen the contact time, creating optimal conditions for maximum penetration of the working body into soil.

The stability of the plane-parallel movement of the working body during penetration into the ground is ensured by the fact that the inertial masses make a rotational movement. The sum of the moments of inertial masses relative to the axis of rotation is equal in magnitude and opposite in sign, which prevents reactive rotation of the body with the bottom and ensures that the conditions for the equilibrium of the system are met.

Equipment for ramming recesses with inertial masses and a movable bottom (Pat. № 1084366). The working body includes (see Fig.7*б*) a hollow body 2 with a movably installed bottom 1, connected to the central rod 6, inertial masses 3 and 5, connected by flexible ties 4, and a gripper 8 connected to the central rod 6 The projections 7, 10, 12 are made along the height of the rod, between which inertial masses are placed, and the distance between the upper projections 7 and 10 exceeds the distance between the lower projections 10 and 12. The body is rigidly connected to the carriage 9 and has a stopper 11 for interaction with the lower inertial mass. weight 3. The upper plane of the stopper is located above the level of the lower annular protrusion of the central rod.

The body with the carriage is lifted along a guide post mounted on the boom of the basic hoisting machine (not shown in the figure). In this case, the inertial masses are in the upper position, the flexible connections 4, with the help of which the lower inertial mass 3 is suspended, are in a stressed state. The body in a suspended state rests through the upper protrusion 7 of the central rod 6 on the upper inertial mass, which is lifted on the gripper 8.

When dropping the working body, the movable bottom 1 first touches the compacted soil, then the lower inertial mass 3 is switched on, which, hitting the lower protrusion 12 of the central rod, acts on the bottom, increasing the pulse duration. Due to the difference in the distances between the projections 7 and 10, 12 and 10, the inertial mass 5 comes into operation later than all. It transfers the impact energy to the ground through the movable bottom, which receives the impact through the projection 10 of the central rod, after which the cycle is repeated.

Equipment for ramming recesses with shock cups (Pat. № 791843). The attachment contains (see Fig.7*в*) a guiding space truss 1, pivotally connected to the boom of the base machine (not shown

in the figure), and a working body made in the form of a hollow body 4, which is a truncated cone or pyramid. The large base of the body is equipped with hollow shock cups 13, which are evenly spaced and rigidly fixed. The shock nozzles are arranged so that the intervals between them are equal to *d*/2, where *d* is the diameter of the shock cup, and the sum of the areas of the shock cups is equal to 0,2-0,4 of the area of the small flat base of the body. The body from the side of the larger base has a horizontally located axis 3, the ends of which are equipped with fixed wedge enclosing guides 9. Part of the body volume is filled with movable masses in the form of cast iron balls 2. Inside the plane of the central shock cup, there is a loop 5, made, for example, of a steel rope with the possibility of limited movement. Spatial truss 1 is equipped with wedge-shaped male guides 8 of rectilinear movement. The lower part of the guides 8 has holes 10 and corresponding locking pins 11. In the place of bearing on the ground, a base plate 12 with pintles is attached to the truss.

Attachments are installed in the place of the future recess, the position of which is fixed using a base plate with pintles. The winch of the base machine by means of a rope 7 and a hook 6, the working body is lifted by the eyelet along the guides 8 to a certain height. Shock cups are in the down position. After lifting, the working body is dropped to the ground. A series of blows with glasses leads to perforation of the soil mass and the formation of compacted soil cores at their base. For the formation of a common soil core and the final ramming of the recess, the working body is rotated 180° around the axis 3. For this, the working body is raised to a height H so that the guides 9 are above the holes 10 in the guides 8, and the locking pins 11 are inserted into the holes 10, which fix the working body at a certain height with the possibility of turning it around the axis 3. Then the hook 6 with the rope 7 is released from the eyelet, the loop 5 is moved inside the pipe of the central glass with the formation of a new eyelet and, by lifting, the working body is rotated in the vertical plane by 180° around the axis 3. During the turn, the moving masses in the form of cast iron balls move from the cavities of the shock cups into the cavity of the body. The working body occupies a vertically stable position.

The supply of the working body with shock cups allows to increase the shock load on the soil mass by 1,5-2 times without

increasing the total mass and falling speed of the device, that is, without increasing the kinetic energy, which leads to an increase in the productivity of ramming depressions with this equipment by 40...50% in comparison with solid mass rammers in the form of a truncated cone.

Equipment for ramming recesses with a metal ballast (Pat. № 1040040). The device mounted on the boom (see Fig. 7*г*) of the base machine contains a guide bar (not shown in the figure) along which the working body moves. The working body includes a body 1 with a vertical channel 2 of circular cross-section and a console 4. The working body is a truncated cone with a side wall slope of 1:8...1:10 and a lower diameter d_2. The ratio of diameters d/d_2 is 0,3...0,35. In the vertical channel 2 there is a hollow cup 11 with a flange 15. At the lower edge of the vertical channel 2 there is an elastic gasket 14. The hollow cup has a bottom 13, and the perforated side walls are openings 12 for air outlet. The limiter of the vertical movement of the cup is a hole in the bottom plate 10 of the working body, the diameter of which is less than the diameter of the vertical channel 2, but into which the glass 11 freely passes. The vertical channel is closed from above by a sealed plug 3. The working body moves along the guide rod using a carriage rigidly mounted on it 4 with a roller 5. The required rigidity of the working body is achieved by installing vertical ribs 7 in its inner cavity, to which the body elements are attached. To achieve the required static pressure on the ground, metal ballast 9 (for example, steel balls) is poured into the cavity of the working body. The specific static pressure of the working body is no more than 0,03-0,035 MPa.

The volume of the cavity of the vertical channel 2 is regulated by changing the location of the plug 3.

The total period of contact of the working body with the ground can be divided into two half periods. The first is the penetration of the working body into the soil, the second is the jump under the action of the elastic forces of the soil medium. In the first period of impact interaction with the ground, the hollow cup 11 first contacts, since it protrudes beyond the bottom 10 of the working body. In the same period, the working body, moving downward, overlaps the cavity of the excavation from communication with the atmosphere, and the air in the cavity of the recess through the holes 12 in the side

walls of the glass is pumped into the cavity 8, covered by the plug 3. Then the bottom plate 10 interacts with the soil, creating on the surface of the bottom of the recess has a ring load of high intensity. In the area under the bottom of the glass 11, the vertical stresses are not equal to zero, since the compressed air in the cavity 8 exerts pressure on the bottom of the glass. Under the action of these compressive stresses, the soil moves under the bottom 10 and the bottom 13 of the glass.

In the second half-period, the working body moves under the influence of elastic aftereffect forces, i.e., the soil is unloaded. However, soil decompaction in the upper contact layer does not occur, since under the bottom 10 it is loaded by the weight of the working body, and under the bottom 13 - by the pressure of compressed air. When the working body is lifted with a rope 6, compressed air, expanding, blows through the annular gap between the bottom plate 10 and the side wall of the cup 11 and pushes this cup out of the vertical channel 2.

The device allows to reduce the mass of the working body by 20-25% due to the presence of a vertical axial cavity and to prevent jamming of the working body in the cavity of the recess due to the action of compressed air.

Equipment for ramming recesses with inertial mass (Pat. №1135841). The rammer consists of a metal body 1 (Fig.8*a*) with a vertical channel in which the inertial mass 3 and the shock absorber 4, installed under the inertial mass, are located. The shock absorber of the spring-friction or hydraulic type is attached to the bottom of the rammer body, the vertical channel in the upper part is equipped with a stop 5. The inertial mass is installed with a gap relative to the stop. Unlike spring dampers, spring-friction and hydraulic dampers make it possible to adjust the recoil time in a much wider range and, if necessary, to stretch it. The latter contributes to an increase in the time of the stress state of the soil and thereby to an increase in the efficiency of compaction. However, the design of the selected shock absorbers does not provide a return of the inertial mass to its original position, and therefore an attachment of the shackle 6 is provided on the inertial mass in the upper part.

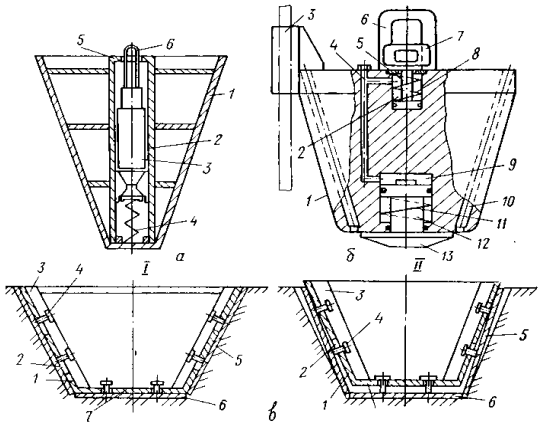

Fig. 8. Working bodies for ramming recesses: *а* - with inertial mass; *б* - with a hydraulic device; *в* - with flexible elastic elements; I - submerged working body; II - extraction of the working body from the soil

The rammer is lifted and dumped using the excavator's lifting mechanism. To carry out a working operation, the rammer, suspended by means of a shackle from the boom of the base machine, is located at a predetermined height above the surface and is dropped. At the moment of contact with the ground, the tamper body 1 and the inertial mass 3 in it have the same speed. In the process of joint movement of the soil and the ramming body 1, the speed of the latter decreases faster than the speed of the mass 3. As a result, the inertial mass creates additional pressure on the lower part of the ramming body 1 through the shock absorber 4, which is transferred to the compacted soil surface.

Upon completion of the impact, the lifting mechanism of the excavator lifts the inertial mass 3 through channel 2 up to the stop 5 with the help of the shackle 6, after which the rammer body 1 begins to rise to the specified height, then the cycle repeats.

The use of a rammer will make it possible to obtain a greater depth of working out of the soil layer, and, consequently, to increase the productivity of work.

Equipment for ramming recesses with a hydraulic device (Pat. № 1057621). The working body (see Fig.8*б*) consists of a housing 1 with a pulling bracket 6, in which an earring 7 is installed with the possibility of longitudinal movement. The earring is attached to the

rod 5 of an additional hydraulic cylinder 2 and has a spring 8. The hydraulic cylinder is connected to the main hydraulic cylinder 9, to the rod 12 of which a tip 13 with a spring 11 is connected. Channels 10 in the body 1 are designed to release air from the pit when the working body is immersed. With the help of the slider 3, the working body is movably connected to the guide structure.

The working body is gradually submerged into the ground by lifting to a predetermined height and dropping to the ramming site. At the same time, to raise the working body, the bracket 6 is grasped with the hook of the load-gripping mechanism of the base machine (not shown in the figure).

If the traction force of the base machine, designed for unhindered lifting of the working body, is insufficient to remove it from the recess, the hook of the load-gripping mechanism is removed from the clamp 6 and introduced into the traction shackle 7, moving it then upward. This leads to the compression of the spring 8 and the displacement of the working fluid from the hydraulic cylinder 2 through channel 4 into the hydraulic cylinder 9, as a result of which there is a simultaneous movement of the housing 1 upward relative to the currently stationary tip 13 and compression of the spring 11. As a result of the significant stroke of the housing 1 and the development in the hydraulic cylinder 9 of a large lifting force, there is a reliable separation of the body 1 from the ground. Then the hook of the load-gripping mechanism is removed from the shackle 7 and inserted into the bracket 6, lifting the working body to a predetermined height. In this case, due to the elasticity of the springs 8 and 11, the working fluid flows from the hydraulic cylinder 9 to the hydraulic cylinder 2 and the shackle 7 and tip 13 return to their original position. Thanks to this design of the working body, it is reliable when working on wet clay soils and provides a high quality of recesses.

Equipment for ramming recesses with flexible elastic elements (Pat. № 909011). The rammer (see Fig.8*в*) consists of rigid side walls 1 forming the body, connected by a bottom 7. In the walls and bottom of the rammer, guide holes 2 are made through which pins 4 pass, with which the rammer is connected to the cladding. The cladding consists of a base 6 and separate additional sheets 5, which are hinged or welded to the base sheet. The edges of the additional

sheets 5 are located with a gap relative to one another. If the working body is filled with concrete (the stiffeners and concrete are not conventionally shown in the figure), the strips in which the holes 2 are located can be fenced off with channels 3. Between the side walls and the cladding there is a thin layer of grease, for which known devices can be used (grooves, nozzles, etc.).

When the working body is immersed in the ground, the lining sheets 5 adhere tightly to the ground and the walls of the stamp and therefore practically work only for compression. This allows them to be made from a thin elastic material. The rammer is in contact with the ground only with its ribs. When it is removed, the friction between the sheets and the ground turns out to be about 3...4 times greater than between the stamp and the sheets. Therefore, the rammer begins to move relative to the cladding, the sheets of which, in turn (under the influence of the elastic force of the compacted soil), due to the gaps between the sheets and their flexible fastening, also approach each other until the pressure on the sheets from the ground decreases so much that the ramming will be extracted by an effort that does not significantly exceed its mass. For tamping with a conical shape, the cladding is suitably made of tapered sheets.

This design of the working body allows you to improve the quality of the pit by preventing the collapse of its walls.

A device for ramming recesses with a flexible cover (Pat. № 958592). The device includes (Fig.9*a*) a body 1, covered by a flexible cover 2, which is attached to the frame 3. The frame has bushings 4 designed to install guide pins in them 5. Through powerful compression springs 6, the frame 3 rests on the body 1. With the help of the suspension unit 7, the device is connected by a rope of the lifting mechanism of the base machine.

After lifting to a predetermined height, the device is dropped to the ramming point. When it is removed from the cavity formed by it, the housing 1 initially moves relative to the stationary cover 2 held by the forces of adhesion to the ground. Due to the fact that the frictional forces between the housing and the cover (especially when it is made of plastic) are extremely insignificant, the lifting force of the housing is spent mainly , to overcome the force of gravity of the device and to deformation of the compression springs.

A device for ramming grooves with a movable rod (Pat. №

1074960). The device consists of a body 1 (see Fig.9 *б*) and a rod 2 placed in it with a base plate 9 attached to it, pressed to the bottom of the body by means of springs 3, levers 4 and rods 7. Flexible protective elements 8 prevent the ingress of soil into the gap between the bottom of the body and the plate.

By gripping the flexible element 5 with the hook of the load-gripping mechanism, the carriage 6 with the body is raised to a predetermined height and dropped to the ramming site. When removing the device as a result of the development of significant forces in the flexible element and due to the ratio of the arms of the levers, forces are transmitted to the body through the rods 7, ensuring its reliable departure from the walls of the recess when moving upward relative to the "head-rod-base plate" system. The device provides high reliability of extraction and reliable operation when ramming high quality recesses.

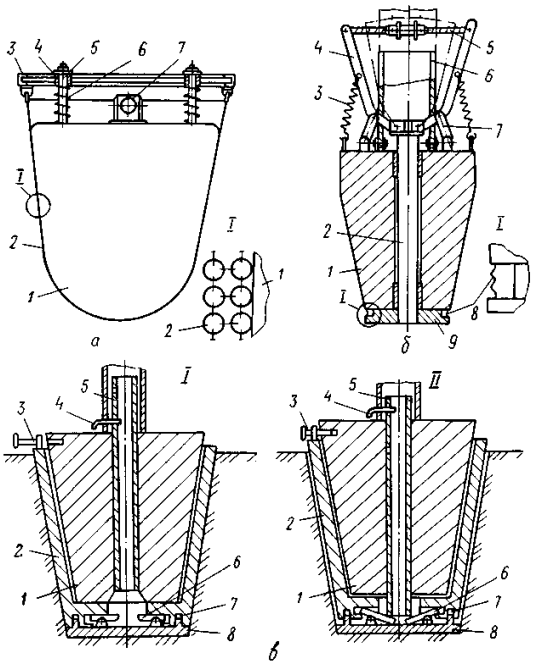

Fig. 9. Devices for ramming recesses: *а* - with a flexible cover; *б* - with a movable rod; *в* - with a transmitting plate; I - submerged working body; II - due to the extraction of the working body from the ground

A device for ramming recesses with a transmitting plate (Pat. № 973706). The device (see Fig.9*в*), installed on the boom of the base machine, includes a guide rod (not shown in the figure), along which the ramming body 1 with a movable stop 5 moves reciprocally; transfer plate 8 with levers 6 truncated cone 2 with grooves 7; clips 3,4.

When ramming the recess, the retainer 3 is disconnected from the rammer, and the movable stop 5 is fixed in the upper position. When removing the rammer, the stop is fixed in the lower position, after which the rammer is dropped. The stop 5, acting on the levers 6, separates the truncated cone 2 from the ground. By connecting the truncated cone with the tamper with the retainer 3, the entire tamper is removed. The use of the device allows you to completely eliminate jamming of the rammer in the ground during ramming.

A device for ramming recesses with separate vertical elements (Pat. № 1043254). A rammer in the form of a regular square truncated pyramid (Fig.10*а*) includes a body of separate vertical elements 1 and 2, connected in pairs by jumpers 4 and 5 and forming movable blocks 10 and 11. The movable blocks interact with each other through rollers 12, installed in the niches of the inner edges of the vertical elements. Channel 3 and socket 9 serve for air release. On the movable block 11, the carriage 8 is rigidly attached for fixed movement along the guide rod (not shown in the figure).

With the help of the winch of the base hoisting machine, by means of the traction rope 7 and the gripper 6, the working body is raised to a certain height and then dropped.

The rammer is reliable in operation due to the elimination of skewing and jamming of the vertical body elements, a small extraction force, as well as the elimination of the possibility of the formation of a soil plug (the walls of the vertical channel for air outlet during ramming move relative to one another).

A device for ramming recesses with a rotary transmission plate (Pat. № 1139798). The device includes a rammer 2 (see Fig.10*б*) in the form of a truncated cone with longitudinal blades 1 and a transmitting base plate 7, movably interconnected by compression springs 3 and radial fingers 5 located in inclined slots 6.

When the rammer is dropped, it moves relative to the transmitting plate by the size of the gap 4 with the simultaneous rotation of the plate around its axis. The consumption of the kinetic energy of the

falling rammer for the compression of the springs is insignificant and does not exceed 5%.

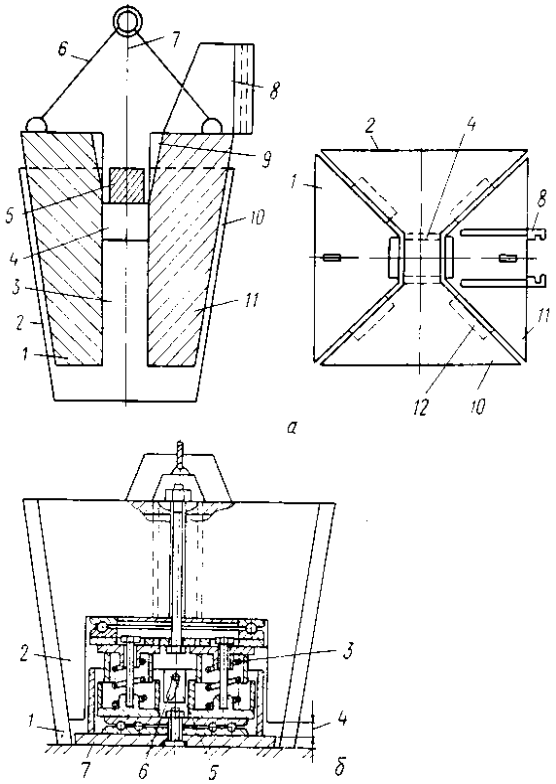

Fig. 10. Devices for ramming recesses: *а* - with separate vertical elements; *б* - with a rotary transmitting plate

A device for ramming recesses with an extraction mechanism (Pat. № 1141162). The device consists (Fig.11*а*) of a basic machine with a frame (not shown in the figure), on which a guide 1 with a working body 6 with a hydraulic lifting mechanism is installed, and outriggers 5, fixed by clamps 4 in guide brackets 3. The brackets are articulated connected to the guide 1, to which the hydraulic power cylinders 2 are also pivotally attached, connected by rods with the corresponding free ends of the brackets 3.

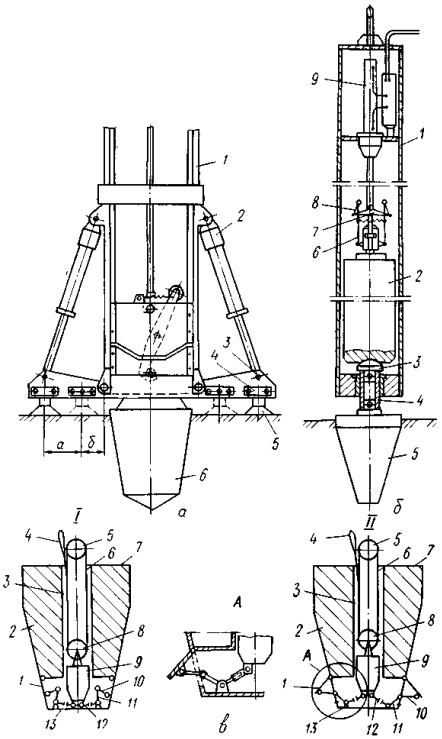

Fig. 11. Devices for ramming recesses: *а* - with an extraction mechanism; *б* - shock action; *в* - with a broadened lower part; I - with closed extension flaps; II - with extended flaps

By changing the size of the arms *а* and *б*, the force required to detach the working body from the walls and bottom of the recess is regulated (depending on the depth and ground conditions). At the moment of separation of the working body, surface compaction of the side walls of the recess occurs, which significantly affects the bearing capacity of the foundation.

The use of this device ensures the minimum energy consumption of separation of the working body from the ground.

A device for ramming of impact recesses (Pat. № 926153). The device is made in the form (see Fig.11*б*) of a tubular body 1, in which the firing pin 2 is freely installed, acting on the shabot 3, which is connected by means of a rod 4 with a working tool - a

stamp 5. The gripping device is made in the form of a traverse 7, pivotally connected to the drive, for example with the rod of the hydraulic cylinder 9, fixed in the housing. The system of connecting rods 6 and rocker arms 8 provides automatic disconnection (when lifting) and connecting (when lowering) the gripper with the shank of the striker.

Due to the fact that the separation of the shank of the striker with the traverse occurs in the process of their simultaneous uniformly accelerated fall, the contact stresses in the areas of mating surfaces are extremely small, which practically excludes their wear.

A device for ramming recesses with a widened part (Pat. № 1048052). The device contains a body 2 of the working body - rammers (see Fig.11*в*), on which the flaps are fixed with hinges - extenders 1. The flaps are pivotally connected through a system of levers 10,11,12 with the bottom of the body 13 and the counterweight 9, which is fixed with hinges, located in the cavity 3 and is suspended by means of a chain hoist 6 to the housing cover 7, the lower block 8 of the chain hoist being attached to the counterweight, and the upper block to the housing cover.

The deepening in the ground is rammed by dropping the rammer along the guide bar using the base machine. After the end of ramming, a loop 4 of the chain hoist is put on the hook of the cargo rope and lifted. The counterweight is lifted and rotated through the system of levers of the extension flaps, which leads to a widening of the recess. When the counterweight is lowered, the extension flaps close.

A device for ramming recesses with retractable sealing cheeks (Pat. № 1074940). The rammer is (Fig.12*а*) a hollow body 1, inside which there are guide rods 5 and a wedge-shaped vertically movable element 2, connected by the upper part to the carriage 11. Sealing cheeks 3 are pivotally connected to the lower part of the body 1, installed on the axes 6 with supports. The cheeks are equipped with rolling bearings 9. The body has locks 10 for moving the sealing cheeks.

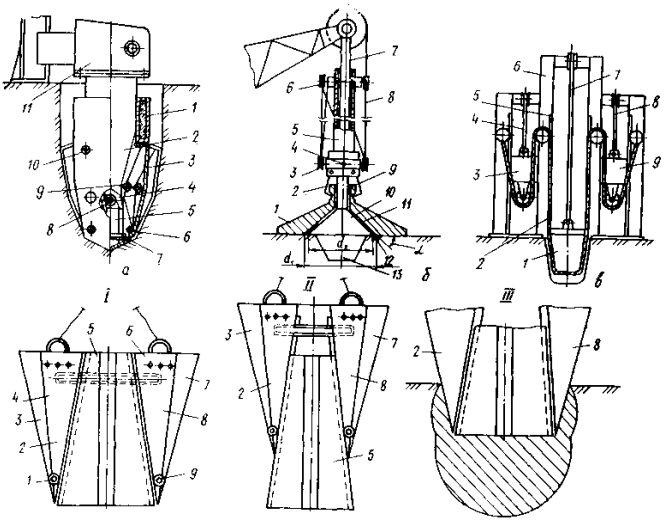

Fig. 12. Devices for ramming recesses: *а* - with retractable sealing cheeks; *б* - with a sealing heel; *в* - with dynamic extraction of the working body; г - with movable percussion elements; I - starting position; II - pre-shock position; III - the formation of a compacted zone

When lifting the carriage along the guide post, the rollers 8 of the wedge-shaped element engage with the hooks 4 and move the sealing cheeks to the upper position. At the moment of impact, the sharpened part of the body of the working body is introduced into the ground, then after stopping the body, the wedge-shaped element continues to move and through the rolling bearings 9 transfers kinetic energy to the sealing cheeks. The latter, moving forward, compact the deepening of the soil in the walls. The angle of rotation of the sealing cheeks, which determines the width of the recess, is set by adjusting the values of the vertical movement of the wedge-shaped element, for which the thickness of the replaceable plate 7 is changed.

A device for ramming recesses with a sealing heel (Pat. № 1184902). The device contains (see Fig.12*б*) a guide rod 5, to which the heel 10 is attached from below, equipped with a spur 13. The telescopic part of the rod 7 is attached to the boom axis of the base machine or to its hook. A block cage 6 is rigidly fixed on the upper part of the pipe, and a platform 4 is mounted on the pipe with the

possibility of vertical movement, carrying the articulated block cage 3 and a coupling mechanism 2 with remote control. The rammer 1 has an element 9 of the coupling mechanism in the upper part, and in the lower part - an open cavity and, similar in shape to the heel 10. The diameter of the cavity d is 5-10 cm greater than the diameter d_2 of the base of the heel, the angle α is 30-60°. Between the blocks of clips 3 and 6, a rope 8 is stored, which goes to the winch of the base machine and forms, with clips 3 and 6, the tamper hoist pulleys. With the help of the mechanism 2, the block cage 3 is connected to the rammer and, during the operation of the winch, rises along the rod 5 to a predetermined dumping height. At the desired height, the gripping mechanism releases the rammer, which falls freely down along the rod. The compacted soil is partially displaced into the gap between the heel and the rammer and forms an interlayer 12, due to which the subsequent blows of the rammer on the heel are somewhat absorbed by the soil.

Device for ramming recesses with dynamic extraction of the working body (Pat. № 1276752). The device (see Fig.12*в*) is installed on the base machine (not shown), to the boom of which a U-shaped post 6 with guides 5 is attached. On them, a working body is movably fixed on a lifting rope 7, on both sides of which they are located in separate guiding shock masses 3 and 5, connected by ropes 4 and 8.

The working body by periodic lifting and dropping is immersed in the ground, while the shock masses are in the upper position and do not interfere with the movement of flexible rods 2, covering the working body. After the immersion of the working body, the shock masses are discharged, interacting with flexible rods, which transmit a dynamic effect to the working body.

A device for ramming recesses with movable percussion elements (Pat. No. 744073). The device includes (see Fig.12*г*) side impact elements 2 and 8 with edges 3,4,6,7, covering the central impact element 5 with sliding guides. In the lateral impact elements, the faces are interconnected by hinges 1 and 9 and fix their position, for example, using a sector lock with a cotter pin, which allows you to change the angle of inclination of the lateral faces when changing the physical and mechanical properties of soils.

In the first period of impact interaction, a central percussion

element is introduced into the soil, which creates a depression with vertical walls and a compacted zone in the face, while the soil on the vertical walls of the depression is loosened. In the second period of impact interaction, impact lateral elements come into contact with the vertical walls of the already created recess, which, under the action of inertial forces, form slopes from the loosened soil.

A device for ramming recesses with a hollow truncated cone (Pat. № 1260442). The device (Fig.13*a*), mounted on the base machine with a boom, consists of a guide bar; working body drive (not shown in the figure); transfer plate 1 with a device for lifting it in the form of compression springs 16 and ledges 2 in the grooves of the hollow truncated cone 4 of the rammer with a lifting loop 15, a bar 18 and a movable stop 8. In the rammer there is a chain link 25 connected by a flexible connection 17 to the drive of the working body. The upper cage 10 of the chain hoist is fixed in a movable stop 8, and on the axis 6 of the lower cage 5, which can be vertically displaced to the stops 7, a grip 13 is installed, which interacts with both the lifting loop 15 and the dump roller 12. The movable stop 8 in the lower part has slots 14 for the lifting loop 15, and in the upper part it rests with its butt end against the collar 9 of the through channel of the rammer during the lifting of the last one. The device, which automatically connects the hollow truncated cone 4 with the rammer 3, has a cam 23 with a working profile 21 facing the center of the rammer. The cam is installed in the vertical hole of the protrusion 22 of the truncated cone 4 and is equipped with a compression spring 20 and a pusher 19 in the form of a bracket with a working roller 24. The roller, moving reciprocally in the hole of the protrusion 22, at a certain moment of immersion of the hollow truncated cone connects and disconnects it from the rammer organ 3 by means of bar 18.

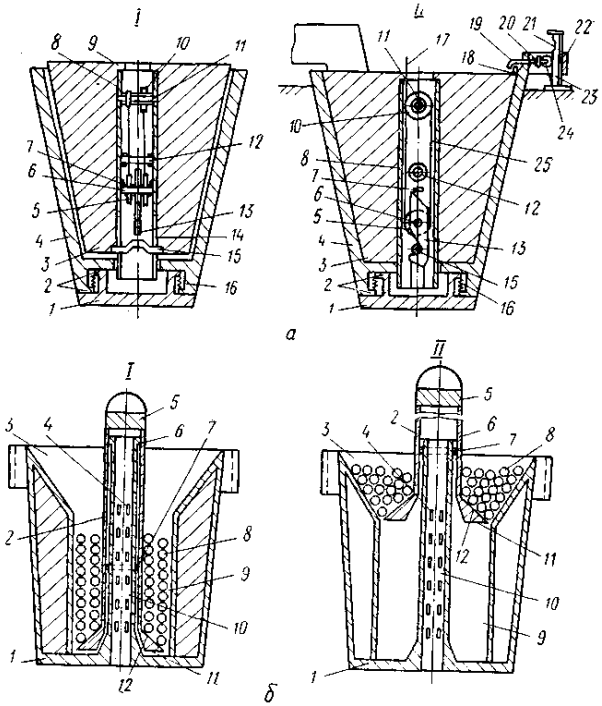

Fig. 13. Devices for ramming recesses: *а* - with a hollow truncated cone; *б* - with inertial bulk material; I - when immersed; II - when extracting

The simultaneous dropping of the rammer and the transfer plate with the hollow truncated cone occurs automatically until the rammer is disconnected from the hollow truncated cone. After that, the ramming body is dropped separately until the hollow truncated cone is completely immersed in the ground. Then the hollow truncated cone is connected with the rammer, their separation from the ground (separation is possible at any immersion value) and further simultaneous lifting.

Device for ramming recesses with inertial bulk material (Pat. №1172995). The rammer includes a body 1 (see Fig.13*б*) with a bottom, an upper chamber 3 and a lower cylindrical chamber 9. A vertical pipe 10 is installed in the center of the rammer with a stop 6 for venting air from under the bottom, which is covered by a rod 2 with a flanged pad 11 at the end. A gripping device 5 with a hoisting rope is mounted on the bar, which has an annular protrusion 7. The

vertical pipe is equipped with 4 holes for air outlet. The flange platform is located under the bulk material 8, for example in the form of steel balls, and its upper edge 12 is made with a slope towards the body.

When dropping the rammer, the bottom touches the ground first, while most of the bulk material is located on the conical surface of the upper chamber, under the action of inertia forces it continues to move down the inclined surface, creating a movable load on the body and thereby increasing the duration of the shock pulse. Then the flanged platform 11 strikes the bottom, and then the impact of the bulk material with increasing energy follows in the form of an avalanche of flying balls, which, in turn, increases the pulse duration, after which the cycle is repeated.

Conclusions:

1. The considered technical solutions ensure the effectiveness of the formation of recesses due to the design features of the working equipment and working bodies. The performed studies show that the parameters of the working body and the impact energy have a significant effect on the efficiency of the formation of recesses.

2. Analysis of scientific and technical solutions in the field of improving working equipment for the formation of recesses without excavation allows us to conclude that it is possible to effectively ram out recesses for foundations without a widened base with freely falling rammers 1-2 m high, with a bottom size of 0,4-1,4 m, at the top 0,7-1,8 m, with a taper (slope) of the side walls from 1:20 to 1:5, and for foundations with a broadened base - with rammers 1,5...3,5 m high, size along the bottom 0,4-1 m, at the top 0,6-1,2 m. The ramming of recesses is carried out by driven working bodies-templates (rammers) with a height of 1,5-2,5 m and a size of 0,9-1 m at the top. The choice of design and parameters of working bodies and working equipment is determined by the size of the deepening, soil conditions and dynamic loads on nearby buildings and structures.

3. Increasing the efficiency of using the working equipment in the considered technical solutions is achieved by reducing the efforts to extract the working body from the soil; using rammers of a special shape to form separate recesses, extended (con-tinuous) recesses and

depressions with a widened cavity; increasing the time of interaction of the working body with the ground; re-duction of dynamic loads on the base machine.

4. Recesses recesses by free falling of the working bodies is most expedient in subsiding soils with low natural density (σ_d<1,7г/см^3) and a degree of moisture S≤0,75. The equipment can be used to form both recesses for the foundations of structures (individual and strip) and recesses that do not require significant bearing capacity, for example, ditches, wells for fence posts, etc. Under the conditions of creating static soil pressure around the working body, it is possible to stamp only individual depressions.

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