Guide for the application of drilling and blasting method of loosening frozen and perennially frozen ground and moraines

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GUIDE FOR THE APPLICATION OF DRILLING AND BLASTING METHOD OF LOOSENING FROZEN AND PERENNIALLY FROZEN GROUND AND MORAINES

IZDATEL'STVO LITERATURY PO STROITEL'STVU
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TRANSLATED BY / TRADUCTION DE

V. POPPE

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PREFACE

Excavation of frozen ground is encountered in many engineering works carried out in northern areas of North America. Explosives are widely used by the Canadian mining industry to excavate frozen overburden and ore in open-pit and underground mines. Much research and development has been carried out to improve drilling and blasting techniques, and to date this is the most economical method of removing large quantities of frozen material.

The efficiency of the blasting operation is dependent upon the type of explosive, the amount and shape of the charges, slot-hole configuration, the depth of charge placement and the sequence of firing. Problems related to incomplete rupture and insufficient fragmentation have greatly reduced the efficiency of blasting in small excavations.

The guidelines presented in this translation outline the experience gained in the Soviet Union in the use of blasting for excavating pits, trenches, and road cuts. It also gives recommendations for blasting excavations in the vicinity of buildings and other structures.

The Division here records its thanks to V. Poppe for translating this paper, and to T.H.W. Baker of this Division, who checked the translation for technical accuracy.

Ottawa
September, 1976

C.B. Crawford
Director
Division of Building Research

NATIONAL RESEARCH COUNCIL OF CANADA
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GUIDE FOR THE APPLICATION OF DRILLING AND BLASTING METHOD OF LOOSENING FROZEN AND PERENNIALLY FROZEN GROUND AND MORAINES

This Guide represents a more detailed treatment of the chapter of SNiP entitled "Earthworks. Methods of work and rules for the acceptance of completed jobs". It was compiled in accordance with the "Unified safety rules for blasting operations".

Introduction

Within the overall construction cycle, working frozen ground is a time-consuming and inadequately mechanized process.

Because of their high mechanical strength, frozen soils cannot be easily worked with conventional earth-moving equipment, and must be loosened with special machines or by blasting.

Blasting of frozen ground is used widely in the Urals, as well as in Western and Eastern Siberia. At the Yuzhuralspetsstroi Construction Trust 80% of the total volume of frozen ground is loosened by the drill-and-blast method. In this way frozen soil is loosened simultaneously throughout the depth of freezing.

Several improved techniques, such as delay-action and contour blasting, as well as the use of stretched* and divided** explosive charges and of the latest drilling equipment make the blasting method of loosening frozen soils more efficient, and extend the range of its applicability.

The aim of this Guide is to help construction engineers and designers to select and apply the most efficient blasting method.

The Guide was prepared by I.P. Balbachan, Yu.A. Ivanov and A.A. Yurko at the Section of Organization, Technology and Mechanization of Earthwork of the

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* The charge is formed in a smaller diameter and its length is increased. (Transl. Ed.)

** The charge is formed into smaller separate charges which are evenly spaced apart. (Transl. Ed.)

Central Research and Design-Experimental Institute for the Organization, Mechanization and Technical Assistance of Construction.

The Guide was revised at the Central Production and Experimental Laboratory of the Soyuzvzryvprom Trust.

1. Brief Description of Frozen Soils

1.1. The cost of working frozen soils is strongly dependent on the climatic and ground conditions. The greater the strength of frozen soil, the more time-consuming the earthworks.

In turn, the strength of frozen soil depends on a number of factors, such as the type of soil, its water content, and the air temperature.

Frozen soil should be regarded as a four-component system consisting of solid mineral particles, a binding substance (ice), water and air. The ice content determines to a large extent the strength of frozen soil. The amount of ice in the soil depends on the air temperature and the soil type: the lower the temperature, the greater the amount of ice formed in the pores; the smaller the grain size of the soil, the lower the ice content in the pores, with all other conditions remaining the same.

The mechanical strength of frozen soil is characterized by the tensile and compressive strength (see Table I).

1.2. The depth of seasonal freezing depends on many factors, the most important of which are: the air temperature, the wind velocity, the thickness of the snow cover, the type and strength of the soil, its water content, thermal conductivity and specific heat, the ground-water table, and the nature of vegetation.

1.3. The depth and rate of freezing have a considerable effect on the earthwork in winter and must be thoroughly investigated prior to the commencement of work. Allowances should be made for the fact that, with all other conditions remaining equal, soils with pores partially filled with water, as well as compact soils with small pores, freeze faster and to a greater depth than loose and dry soils, since thermal conductivity of the former is greater. The closer the ground-water table to the surface, the smaller the depth of freezing of the soil. Clays freeze slower than sands. The greater the content of large particles in sand, the faster its rate of freezing and the greater its depth of freezing.

2. Organization of Work. General Instructions

2.1. Prior to drilling and blasting a work order must be prepated indicating the required number of drills (or slot-cutting machines) and earth-moving machines, which will depend on the volume of work to be performed, the depth of freezing, and the width of the trench or pit.

The work order must contain provisions for a timely preparation of the site, a trouble-free operation of the earth-moving equipment and motor transport, keeping the number of oversize lumps of loosened earth materials to a minimum (not more than 3%), as well as for work safety and good maintenance of equipment. The time schedules must be such as to ensure that frozen ground is blasted immediately prior to further work, since otherwise loose soil may freeze again.

2.2. To ensure a continuous operation on sites free of buildings and other structures, blasting must be done using detonating fuses, and not caps, since this makes it possible to charge the blastholes without interrupting the work of earth-moving equipment and motor vehicles in the immediate vicinity.

2.3. Universal use of detonating fuses in the vicinity of buildings and other structures is not recommended, since this would increase the force of shock waves.

2.4. Oversize lumps of earth materials are those whose largest cross sections exceed the following measurements:

(a) For excavators with direct and reversed shovels - 2/3 of the width of the bucket;

(b) For dragline excavators - ½ of the width of the bucket;

(c) For scrapers - 2/3 of the depth of excavation;

(d) For bulldozers and graders - ½ of the height of the heap;

(e) For dump trucks - ½ of the width of the body, or if the weight of the lump exceeds the specified load capacity of the truck.

3. Blasting Methods and Equipment

3.1. There are three methods of loosening frozen ground by blasting:

(a) Shot-holes,

(b) Blastholes, and

(c) Slots.

3.2. The choice of the blasting method depends mainly on the volume of work to be performed, the presence or absence of buildings and other structures on the site, the type of excavation (pit, trench, road cut, etc.), the depth of freezing, the time schedule, the available drilling or slot-cutting equipment, and the method of further earthwork. The selected method must be recorded in the work order.

Shot-hole method

3.3. The shot-hole method is used if the depth of freezing does not exceed 1.2 m, and mainly in the construction of trenches and small pits, in levelling the surface of the ground, and in confined space. The depth of freezing on the construction site is determined by drilling control holes.

3.4. The charges are placed in shot holes up to 75 mm in diameter and having a depth equal to 0.95 of the depth of freezing.

3.5. The distances between shot holes in the same row and between different rows range from 0.8 to 1.4 W, depending on the strength of soil and the purpose of blasting (see Table III). The shot holes are arranged in staggered rows or in a square grid pattern.

3.6. The shot hole is filled with stemming at least 1/3 of its length. Stemming normally consists of sand and rock flour.

3.7. The dimensions of shot holes must be such as to accommodate the designated weight of the charge. The capacity of the charged part of the shot hole is determined from the following formula:

$$Q_{\text{Ш}} = (l_{\text{Ш}} - l_{3})\ P\ \text{kg} \qquad (1)$$

where $l_{Ш}$ is the length of the hole in m,

$l_{З}$ is the length of stemming in m, and

P is the capacity of one m of hole in kg/m (see Table II).

3.8. The size of the charge is determined from the following formula:

$$Q = qW^3, \qquad (2)$$

where q is the specific consumption of explosives in kg/m^3,

W is the computed line of resistance in m, equal to the depth of placing the charge.

For organic and sandy soils, q is taken as 0.4 to 0.55; for suglinoks*, 0.6 to 0.7; for clay and construction waste, 0.7 to 0.9 kg/m^3.

Blasthole method

3.9. The blasthole method is effective in the Far North, the East, and in Siberia, in places where the depth of freezing exceeds 1.8 m. It should be used in the construction of trenches, pits and road cuts with large cross sections, as well as in stripping operations.

3.10. The explosive charges are placed in blastholes 75 to 140 mm in diameter.

3.11. The holes are drilled to a depth equal to 0.85 - 0.9 of the depth of freezing.

3.12. Either stretched or divided charges are used, depending on the depth and mode of freezing and the extent to which the soil must be loosened. Stretched charges are recommended if the frozen layer does not exceed 2.5 m in thickness. Divided charges should be used if the frozen layer exceeds 2.5 m in thickness.

Experience has shown that the top part of the charge must make up 1/3 and the lower part 2/3 of the total weight of the charge. The space between the

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* "suglinok" - clayey silt with some sand, clayey silty loam; contains 10 to 30% clay by weight with clay particles less than 0.005 mm in size. (Transl. Ed.)

part charges is filled with stemming in the form of drill flour, sand or other loose local material. The main parameters of shot-hole and blasthole charges are summarized in Table III.

3.13. Visco-plastic permafrost has a higher blastability coefficient which makes it more difficult to work in such soil, and increases the specific consumption of explosives.

3.14. In the case of permafrost, the specific consumption of explosives must be increased by 20 to 30% as compared with the values in Table III.

Slot method

3.15. The slot method developed at the aforementioned Central Institute is based on the combined effect of charged and uncharged preshear slots.

3.16. The uncharged slots form new exposed surfaces and compensating spaces to enable the soil to shift during the explosion (the impact shear principle).

3.17. The slot method should be used in the construction of trenches and pits in soils frozen to a depth of 0.8 to 2 m.

3.18. The slots are cut in frozen ground with disc-scarifiers or ripper teeth.

3.19. The slots should be cut perpendicular to a protected object since, on blasting, soil is scattered in both directions from the slot.

3.20. The parameters of slots are as follows:

(a) The depth of charged slots - 0.9 of the depth of freezing (0.95 in the case of a considerable depth of freezing);
(b) The width of slots - 100 to 300 mm;
(c) The distance between charged and uncharged slots (between their edges) should not be less than 0.9 of their depth, but not more than 1.8 m (based on calculations and tests).

3.21. Divided or stretched explosive charges are placed in every second slot.

Stretched charges are used if explosives are in cartridges or if (in accordance with the specific consumption of explosives) the height of the cross section of the charge is at least 2/3 of its width. Ribbon charges* should not be used for this purpose. Divided charges should be used in all other cases; part charges are placed every 0.5 to 0.6 m (as determined by tests) throughout the length of the slot.

A detonating fuse is placed throughout the length of the slot prior to charging.

3.22. If slots are over 1.5 m in depth, use may be made of two stretched or divided charges separated by a layer of stemming 0.3 to 0.5 m in thickness (Figure 1).

Best results are obtained by using a continuous charge at the bottom and a divided charge weighing 1/3 of the total weight of explosives in the slot on top.

3.23. In the construction of trenches up to 1.3 m in width use is made of two slots, one of which is charged and the other serves as a preshear slot. The external wall of the charged slot is protected by using explosive cartridges attached to a detonating fuse. The charge is placed at the wall to be blasted.

3.24. In the construction of trenches over 1.3 m in width, three or more slots should be cut. Charges are placed in the centre slots throughout the length of the slot. The outer slots, which correspond to the walls of the trench, must not be charged. In this way the trench walls are protected from collapse during the blast.

3.25. In the construction of pits, delay-action blasting must be used with four stages of delay.

3.26. Stemming material is placed in the charged slots by means of a bulldozer.

3.27. If the thickness of frozen ground is over 2 m, and hence exceeds the technical capabilities of slot-cutting machines, frozen ground must be worked

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* These are long thin charges with limited strength. (Transl. Ed.)

layer by layer.

3.28. The specific consumption of explosives (q) which will ensure that the largest lump of frozen soil will not exceed a given size is found from the following formula:

$$q = B \frac{W_0^2}{X_{max}^3} f(m) \ kg/m^3 \qquad (3)$$

where B is 0.006 for frozen sand, 0.008 for suglinok, and 0.01 for clay (determined experimentally at the Central Institute);

W_0 is the depth of placing the charge, m;

X_{max} is the diameter of the largest lump, m;

$m = \frac{a}{W_0}$ is the coefficient depicting the proximity of slots to each other (a is the distance between the slots in m);

f(m) is the function of the above coefficient (Table IV).

X_{max} depends on the width of the excavating bucket or other equipment used (see paragraph 2.4):

$$X_{max} = \frac{2}{3} b \ m, \qquad (4)$$

where b is the width of the bucket.

Example:

$$b = 0.6 \ m;$$

$$X_{max} = \frac{2}{3} 0.6 = 0.4 \ m;$$

at $W_0 = 1.3$ m and $a = 1.6$ m, $m = 1.23$.

From formula (3): $q = 0.008 \frac{1.3^2 \cdot 4.9}{0.4^3} = 1 \ kg/m^3$.

3.29. To achieve the required design of the trench and reduce the number of manual loading operations in places where it is difficult to cut frozen ground (high-strength soils, rock inclusions, etc.), shot holes or blastholes may be drilled between the preshear slots.

3.30. The method of loosening frozen ground by means of slots has important advantages over the shot-hole or blasthole method, since it makes it possible to cut trenches with smooth walls (Figure 2), reduces the amount of manual labour, improves the results of blasting (better crushing and less scattering of fragments), reduces the operational costs by 30% and increases labour productivity.

4. Drilling and Slot-cutting Equipment

4.1. Shot holes and blastholes are drilled with the ER-16, SER-19 and SER-20 electric drills and other machines of the auger type, as well as by the thermal method.

Rotary auger drills are simple, light and, as a rule, can be operated by one man.

The most advanced auger drills are the BTS-60, the M-3, the SKB Mosstroi, the SBUDM-ZIV-150 based on the ZIL-157 motorcar, the S-1035"S" and the ShPA-2.

The S-1035"S" (Figure 3), the ShPA-2, and the SBUDM-ZIV-150 drills are highly productive and mobile and have a self-contained power supply, which is very important in places without any sources of electric power (Table V).

4.2. The augers are made from special metal pipes with steel strips wound around and welded onto the pipe surfaces. To prolong the service life of augers, a hard alloy is welded on at some points to the edges of the first three or four turns of the steel strips. Bits reinforced with plates of high-strength alloys are mounted at the end of drill rods.

4.3. Slots are cut with disc-scarifiers and rippers of various types, as well as with the ETR-132A rotary excavator (Table VI).

5. Explosives and Methods of Blasting

5.1. It is recommended that water-resistant explosives, such as ammonite 6ZhV, detonate 10-A, etc., be used.

5.2. It is recommended that the electric method of blasting be used.

5.3. Use should be made of detonators, electric detonators (instant, delay-action, and short-delay detonators), detonating fuses and pyrotechnical relays.

5.4. The recommended short-delay detonating method (Figures 4 and 5) has the following advantages over instant detonating:

(a) More soil is loosened per running meter of drilling;

(b) The seismic effect of the blast on buildings and other structures is weaker;

(c) The direction and nature of the ground break-up can be controlled;

(d) The radius of scattering of soil fragments is reduced.

5.5. The optimum delay is determined as follows:

$$t = AW \text{ m/sec}, \qquad (5)$$

where A is a coefficient which depends on the strength of soil; for frozen soil A = 10 to 15 (the lower value corresponds to high-strength soils);

W is the line of least resistance equal to the thickness of the frozen layer, in m.

In practice the delay ranges from 15 to 25 msec.

5.6. Short-delay blasting is carried out with the help of specified short-delay electric detonators and the KZDSh-58 or KZDSh-62-2 relays. The detonators can be placed directly in the charge or can be connected to the fuse at the mouth of each borehole or group of boreholes.

5.7. The pyrotechnical relay is used if the number of delay stages of the detonator is not sufficient, or if the blasting zone is dangerous because of stray currents. Blasting with the use of detonating fuses is done by including the relay in the circuit and connecting the fuse to the relay and to the circuit. Great care should be taken to make certain that the direction of detonation in the circuit coincides with the direction of the indicator in the relay.

6. Loosening of Moraine Soils

6.1. The composition of moraine soils is not uniform. They contain mostly silt particles, sand and boulders. The content of boulders varies widely and may be as high as 70%.

6.2. Boreholes are drilled in moraine soils with the BTS-2 drills and rotary-percussion drills with immersed pneumatic strikers.

6.3. Divided explosive charges must be used if the soil is to be loosened to a depth of over 2 m, as well as to improve the breakdown of the soil.

Concentrated charges placed in the bottom part of the hole will not fracture the boulders close to the surface of the ground.

Divided charges must be made up in accordance with local conditions and the results of experimental blasting.

6.4. Contour blasting should be used if the trenches and pits are to be provided with well-constructed slopes. In this case blasting is carried out in holes drilled at an angle equal to the angle of slope (but not exceeding 1:0.67, i.e., 55°). Boreholes for less steep slopes cannot be drilled in moraine soils.

Inclined boreholes for contour blasting are drilled every 0.8 - 1 m.

Moraine soils are loosened by delay-action blasting, since lumps of both frozen and thawed moraine soil are scattered for larger distances than other types of soil.

7. Protective Devices

7.1. If blasting is carried out in the vicinity of buildings and other structures, various protective devices must be used to protect men and equipment from flying lumps of frozen soil and from shock waves.

7.2. It is recommended that the following types of protective devices be used.

(a) Shields made from metal sheets measuring 1.5 × 2.5, 2.2 × 3 or 2 × 4.5 m and 4 to 30 mm in thickness (Figure 6).

The shields are designed in accordance with the following formula:

$$P_y = W \gamma_r N_g, \tag{6}$$

where P_y is the weight of the shield per 1 m^2 of the protected area in kg/m^2;

W is the thickness of the frozen layer in m;

γ_r is the unit weight of soil in kg/m^3;

N_g is a coefficient depicting the relative weight of the charge, and equal to 0.33 - 0.35.

$$N_g = \frac{Q}{K_{H.B} W^3}, \tag{7}$$

where Q is the computed weight of the charge, and

$K_{H.B}W^3$ is the weight of a standard charge.

(b) Anchor chains joined together with iron rings to form mats (Figure 7 and Table VII). The weight of a mat per 1 m^2 of area is calculated from the following equation:

$$P_y = 0{,}22\, W \gamma_r N_g \ \text{kg/m}^2 \tag{8}$$

(c) Metal "huts" weighing 5 tons (Figure 8) and big enough to cover six holes with a charge weighing up to 2 kg.

(d) Mobile localizer LV-64-02 (Figure 9), which eliminates scattering of lumps of frozen soil during blasting in the vicinity of buildings and other structures. It represents a trolley on eight wheels. A metal plate with an additional load is mounted within the inner frame of the trolley and can be moved by means of cables and hydraulic cylinders. The localizer is pulled by a tractor.

Technical characteristics of the LV-64-02 localizer

Basic unit. . . . . welded trolley with a flat bottom

Measurements in mm:

Length	6,075
Width	3,190
Height	670

Weight in kg:

Without ballast	2,200
With ballast	6,000-9,000

The first three types of protective devices limit scattering of soil lumps to 20 m, while the localizer eliminates scattering altogether.

8. Safety Measures

8.1. The main safety measure is the use of delay-action blasting with divided charges and provision of slots. The slots serve as a seismic screen and are cut to a depth equal to the depth of freezing (up to 2 m). In this way the seismic effect in the immediate vicinity of blasting is reduced by a factor of 2 - 2.5.

8.2. In the presence of slots, the radius of the seismic zone for buildings and other structures is determined from the following formula:

$$R_c = K_Г K_З K_Э \frac{\sqrt[3]{Q}}{\sqrt{n}}, \qquad (9)$$

where $K_Г$ is a coefficient which depends on the ground conditions (for suglinok and supes* $K_Г$ = 8 to 9);

$K_З$ is a coefficient which depends on the depth of the charge at the boundary between thawed and frozen soil, $K_З$ = 0.75;

$K_Э$ is a coefficient which accounts for the screening effect, $K_Э$ = 0.5;

Q is the total weight of charges in kg;

n is the number of delay stages in the group of charges to be detonated.

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* "Supes" - silty sand with clay, sandy silty loam; contains 3 to 10% clay by weight with clay particles less than 0.005 mm in size. (Transl. Ed.)

8.3. Distances beyond which men and equipment will be safe from flying lumps of frozen soil and effects of shock waves must be given in the blasting permits. Such permits containing allowances for local conditions and the "Unified safety rules for blasting operations" must be issued for each construction project.

APPENDIX

Example of Calculation of Shot-hole Charges

Initial data

Soil: frozen suglinok. Depth of freezing h = 1 m. Shot holes are drilled with a BTS-60 drill to a depth of 0.95 m. Shot-hole diameter 60 mm.

Computation and placement of charges

The size of the charge is determined from equation (2).

The specific consumption of explosives (q) for suglinok is determined from Table III (soil group II): $q = 0.6\ kg/m^3$.

The computed line of resistance is taken as W = 0.95 m.

Substituting the above values into equation (2) we find:

$$Q = 0.6 \times 0.95^3 = 0.6\ kg.$$

The length of stemming must not be less than 1/3 of the length of the hole, i.e., 0.3 m, which means that the charged part of the hole will be 0.7 m long. Let us check whether this is long enough for the computed weight of the charge. According to Table II, one running meter of 60 mm holes accommodates 2.56 kg of explosives, i.e., there is ample room for the charge.

The holes are drilled in a square grid pattern. The distance between holes is taken as W = 1 m.

The safe distances during blasting are determined from the "Unified safety rules for blasting operations".

Example of Calculation of Blasthole Charges

Initial data

Soil: frozen clay. Depth of freezing h = 2 m. The holes are drilled with an S-1035"S" drilling machine to 0.9 of the depth of freezing. The hole diameter is 90 mm.

Computation and placement of charges

The size of the charge is determined from equation (2).

From Table III: $q = 0.8\ kg/m^3$.

The computed line of resistance is taken as W = 1.8 m.

Substituting the above values into equation (2):

$$Q = 0.8 \times 1.8^3 = 0.8 \times 6 = 4.8 \text{ kg.}$$

The length of stemming must not be less than 1/3 of the length of the hole, i.e., 0.6 m. Hence the charged part of the hole is 1.4 m long.

According to Table II, one running meter of hole accommodates 5.7 kg of explosives, hence 1.4 m will accommodate 5.7 × 1.4 = 7.9 kg. Therefore the computed weight of the charge (4.8 kg) can be easily accommodated in the hole.

The holes are drilled in a square grid pattern. The distance between the holes and between the rows of holes is 0.8 to 1.4 W. For clays in group III the distance between the holes is 0.9 W, i.e., 0.9 × 1.8 = 1.6 m; the distance between the rows of holes is 1.5 m.

The safe distances during blasting are determined in accordance with the "Unified safety rules for blasting operations".

Example of Calculation of Slot Charges

Initial data

Soils: frozen suglinok (group II). Depth of freezing h = 1.1 m. Depth of slot W_0 = 1 m; the distance between slots a = 1.1 m.

Computation of charges

The specific consumption of explosives which guarantees the given size of the largest lump of frozen soil is determined from formula (3). For suglinok B = 0.008.

$$m = \frac{a}{W_0} = \frac{1.1}{1} = 1.1.$$

From Table IV, f(m) = 4.2.

The size of the largest lump is equal to 2/3 of the width of the excavator bucket. If this width is 0.6 m,

$$X_{max} = \frac{2}{3}\, 0.6 = 0.4 \text{ m}.$$

The specific consumption of explosives is:

$$q = 0.008 \frac{1^2}{0.4^3}\, 4.2 = 0.6 \text{ kg/m}^3.$$

The safe distances during blasting are determined from the "Unified safety rules for blasting operations".

Table I

Compression and tensile strength of frozen soil

Soil temp. °C	Sand w = 20%		Supes w = 22 - 23%		Suglinok w = 20%		Clay w = 33 - 35%	
	Strength in kg/m^2							
	Tensile	Compress.	Tensile	Compress.	Tensile	Compress.	Tensile	Compress.
-5	29	85	22	60	no data		16	40
-15	38	155	39	120	36	no data	23	60
-25	45	195	50	170	44	"	30	85
-40	52	235	57	210	54	"	30	103

Remarks. w - water content by wt., %. Supes - sandy silty loam
Suglinok - clayey silty loam

Table II

Capacity of 1 m of hole in relation to its diameter when charged with powdery or granular explosives having a density of 0.9 kg/m^3

Hole diam., mm	Cap. of hole P, kg/m	Hole diam., mm	Cap. of hole P, kg/m	Hole diam., mm	Cap. of hole P, kg/m
25	0,44	47	1,57	75	4,02
26	0,48	48	1,64	80	4,5
27	0,52	49	1,7	90	5,7
28	0,56	50	1,77	95	6,4
29	0,6	51	1,85	100	7,1
30	0,64	52	1,92	105	7,8
31	0,68	53	1,99	110	8,6
32	0,73	54	2,07	115	9,4
33	0,79	55	2,15	120	10,2
34	0,82	56	2,23	125	11
35	0,82	57	2,31	130	12
36	0,92	58	2,39	135	12,9
37	0,97	60	2,56	140	13,8
38	1,07	65	3		
39	1,08	67	3,19		
40	1,14	68	3,3		
41	1,18	69	3,35		
42	1,25	70	3,48		
43	1,31	71	3,58		
44	1,37	72	3,68		
45	1,44	73	3,78		
46	1,5	74	3,89		

Table III

Main parameters for the computation of charges

Soil group	Thickness of frozen layer, m	Depth of hole, m	Line of resistance, m	Distance between holes in one row, m	Distance between rows of holes, m	Spec. consump. of explosives, kg/m^3	Weight of charge, kg
I	0,5 0,75 1 1,5 2,2	0,5 0,7 0,95 1,3 1,9	0,5 0,7 0,95 1,3 1,9	0,5 0,75 1 1,5 2	0,5 0,75 1 1,5 2	0,5	0,22 0,34 0,5 1,7 5,3
II	0,5 0,75 1 1,5 2 2,2	0,5 0,7 0,95 1,3 1,8 2	0,5 0,7 0,95 1,3 1,8 2	0,5 0,75 1 1,3 1,5 1,5	0,4 0,6 0,9 1,2 1,5 1,5	0,6	0,26 0,4 0,6 2,1 4,8 6,4
III—IV	0,5 0,75 1 1,5 2 2,2	0,5 0,7 0,95 1,35 1,8 2	0,5 0,7 0,95 1,35 1,8 2	0,5 0,75 1 1,3 1,5 1,5	0,4 0,6 0,8 1,3 1,3 1,3	0,8—1	0,38 0,5 0,8 2,8 6,4 8,5

Remarks. The soil group is determined from the average time required to drill 1 m of hole with equipment available on the site (by methods described in ENiR, sb. 2 "Zemlyanye raboty", vyp. 3, "Buro-vzryvnye raboty", 1969).

Table IV

Values of f(m)

m	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	1,4
$f(m)$	4,1	3,4	3,2	3,1	3,2	3,4	3,6	4	4,2	4,9	5,3	6,1

Table V

Technical characteristics of rotary auger, cutting and percussive-rotary drill rigs

Characteristic	Unit of meas.	BTS-60	M-3	SKB Mosstroi	SBUDM-ZIV-150	ShPA-2	S-1035"S"	BTS-2*	SBMK-5**
Diameter of hole	mm	65	80-120	60-120	110	80-100	60-100	To 350	105
Depth of drilling	m	2	2-4	To 4	2-4	2-4	2.5	30	20-25
No. of operating units	-	2	1	3	2	2	2	1	1
Drive	-	-	Hydraul.	Elect.	Mech.	Elect.	Mech.	Mech.	Elect.
Power of electrical motor	kw	10	-	16.5	-	10	-	-	2.8
Rotation velocity	rpm	300-450	540	540-270	-	-	250-500	-	41
Means of movement	-	Self-propelling		Self-propelling	Self-propelling	Self-propelling		Self-propelling	Tracked and self-propelling
Dimensions:									
Height	mm	2,750	3,000	3,250	-	-	3,010	3,600	-
Length	mm	4,530	-	7,050	-	-	5,690	7,420	-
Width	mm	1,926	870	2,580	-	-	-	2,800	-
Output	m/shift	200-300	300	200-250	500-600	400-500	500-600	To 300	-

* Cutting drill for solid rock and moraine soils.

** Percussive-rotary drill for solid rock and moraine soils.

Table VI

Technical characteristics of slot-cutting machines

Machine	Output, lin. m/hr	Depth of slot, m	Width of slot, m	Vel. of cutting unit, m/sec	Basic machine	Distance between slots, mm
Disc-cutting machine	50-80	1.2	0.16	-	Tractor	-
Double ripper	25-60	2	0.14	2.6 1.3	"	560
Double ripper	21	2	0.3	-	"	-
Ripper	15	2	0.14	1.6 2.5	"	-
Ripper	15	1.6	0.14	3.2	Excavator	-
Ripper	14	1.2	0.14	1.4 2.33	"	-
Ripper	16	1.6	0.14	1.75 2.85	"	-
Rotary cutter	50-100	1.3	0.22-0.26	-	Tractor	-

Table VII

Chains for protective shields

Chain thick-ness, mm	Length of one link, mm	Width of one link, mm	Wt. of 1 lin. m of chain, kg	Wt. of 1 m^2 of chain, kg
26	143	91	14,9	164
28	154	98	17,2	176
30	164	105	19,8	188
34	187	119	21,8	206

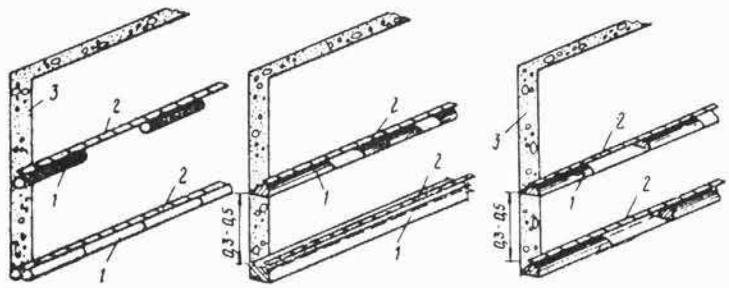

Fig. 1

Distribution of charges throughout the height of the slot and throughout the cross section of charges (loose and sheathed explosives)

1 - explosive charge, 2 - fuse, 3 - stemming

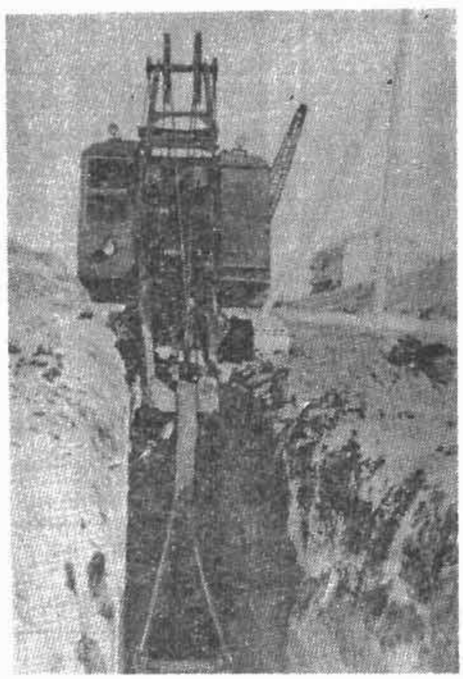

Fig. 2

Trench cut in loosened soil

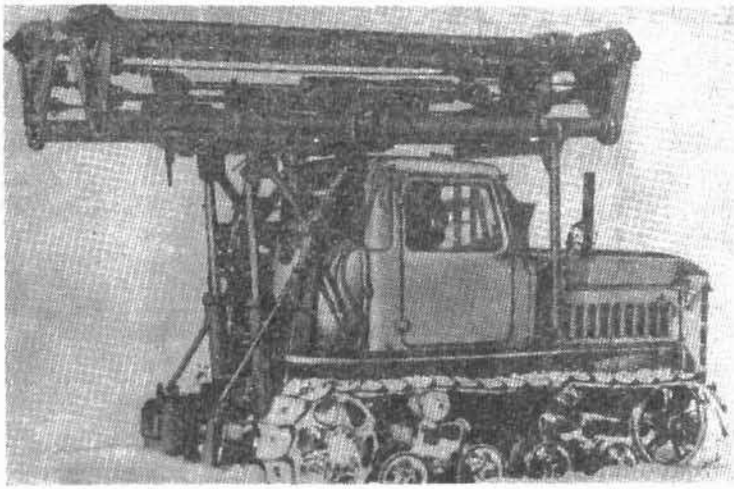

Fig. 3

Drilling machine S-1035"S"

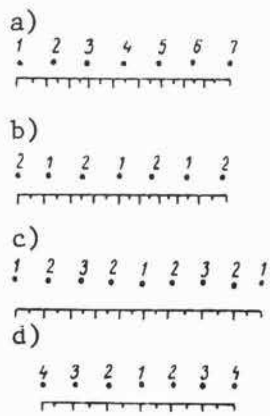

Fig. 4

Layout of single-row delay-action blasting

a - all holes in succession; b - every second hole; c - wave pattern; d - cut holes. Numbers indicate the order in which charges are detonated

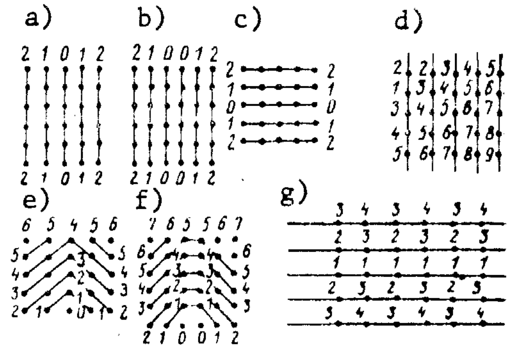

Fig. 5

Layout of multirow delay action blasting

a - with one longitudinal row of cut holes;
b - with two longitudinal rows of cut holes;
c - with cross holes; d - with V holes;
e - with trapezoidal holes;
f and g - layout for blasting trenches.
Numbers indicate the order in which charges are detonated

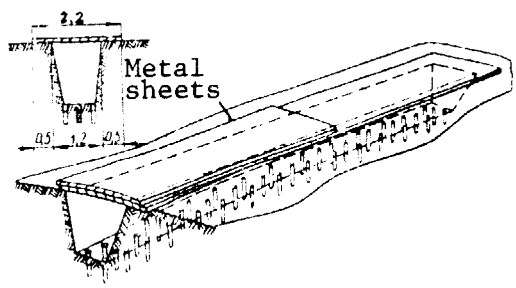

Fig. 6

Shields made from metal sheets

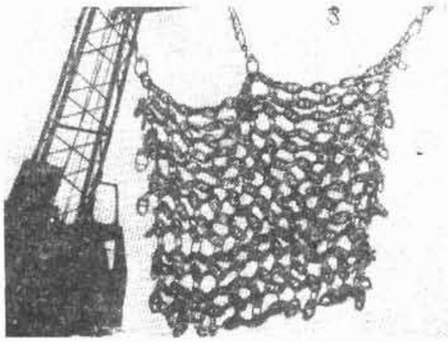

Fig. 7

Shields made from anchor chains

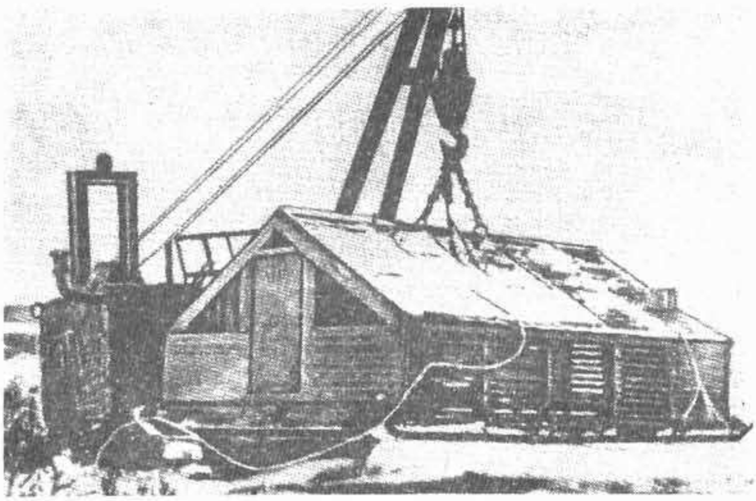

Fig. 8

Metal "hut"

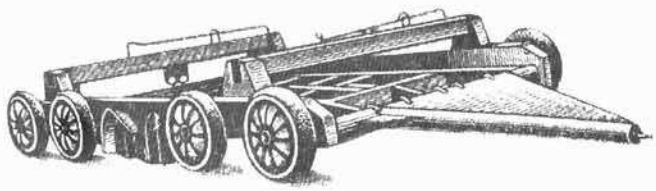

Fig. 9

Localizer