PAPER • OPEN ACCESS

Substantiation of process parameters in separation of large-size granite blocks from a rock mass

View the article online for updates and enhancements.

Substantiation of process parameters in separation of large-size granite blocks from a rock mass

PN Tambovtsev* and AA Neverov

Chinakal Institute of Mining, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

E-mail: *tambovskiyp@mail.ru

Abstract. On the basis of experimental data, a technological scheme to separate large-size granite blocks from a rock mass by an impact method is proposed, the process parameters of block preparation for separation are verified by physical modeling, and a rock-breaking tool is proposed; the dependence of the main crack length vs. impact parameters is determined.

1. Introduction

In the world practice the drill-and-blast and mechanical rock-breaking processes are used to produce stone blocks [1–4]. The present paper deals with consideration of a process for separating large-size granite blocks from a rock mass by applying the percussion breakage of rocks under the tension strain effect. The general process diagram is shown in Figure 1. A rock mass is stripped in the front-and-flat manner with a pass length multiple of a final block length; thereto a width and height of the pass is equal to width and height of a block. The diagram implies availability of three open surfaces of a stone block, a natural fracturing in a rock bed, end slot dozing, drilling of blasthole rows at vertical rear and end surfaces. After delineation of blocks with blastholes one or few impact tools (special wedges) are intruded into blastholes at rear surface and separate a monolith from a rock mass; next, they are inserted into blastholes at end surfaces; and a monolith is divided into final blocks.

2. Technology of granite blocks separation

The working member of the tool (Figure 1c) is made as a two-step cylindrical bar with a taper flange *12* [5]. When the tool penetrates into a hole the surfaces of taper flange between taper planes *13* act with horizontal resultant force F on hole walls (Figure 1d). Downhole penetration of the tool results in wedging of a rock mass and growth of a crack.

The specific feature of the wedge tool is that it provides an acceptable opening of crack edges δ in the zone nearby a blasthole with a downhole tool. Excessive values of δ promote an increase in bending stress in a crack tip with possible breakout of the main fracture through the front surface of a bench. A direction of crack growth is governed by a set of factors, viz., location of blasthole rows at a preset surface, taper surface of the tool relative to the normal to a crack plane, and admissible opening of a crack $\delta = d_1 - d$ (Figure 1c).

Main parameters of block separation from a rock mass are (Figure 2): H—bench height (a block); B—width of a pass (a block); L—length of a block; L_1—length of a working area; d—blasthole diameter; h—blasthole length; a—pitch of blastholes; b—pitch of tool installation; A_{ed}—impact energy; n—number of impacts.
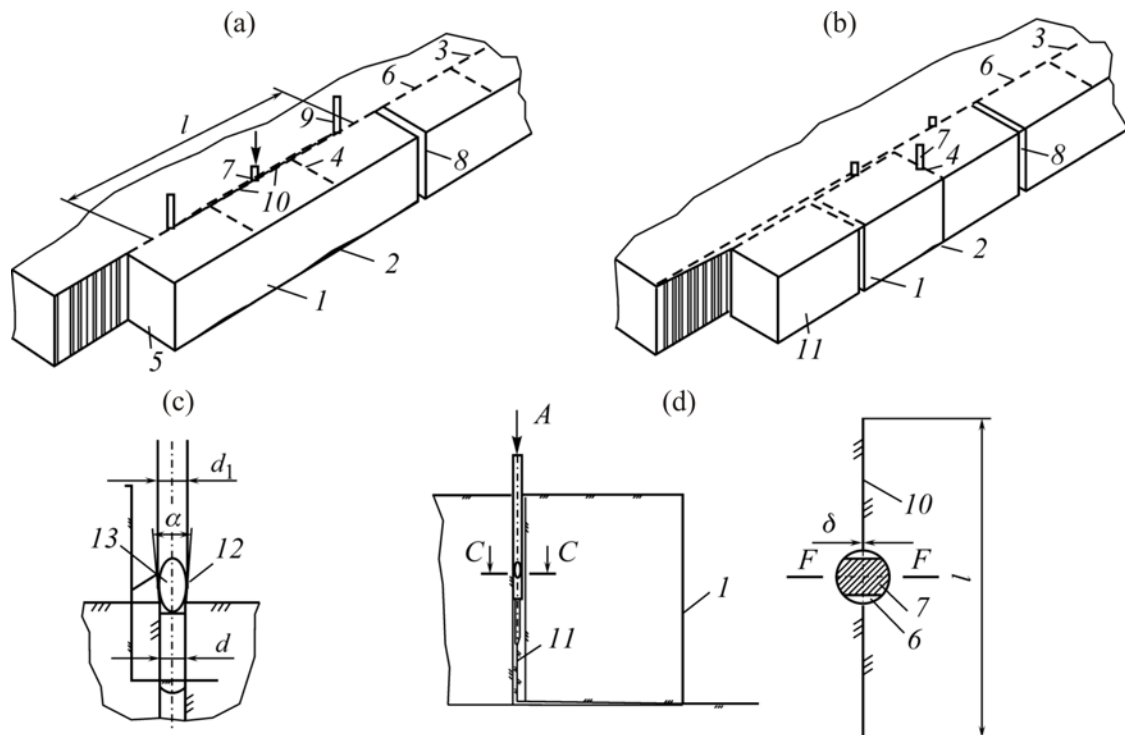
Figure 1. Technological flow sheet to separate stone blocks from a rock mass by drill-and-wedge process with formation of the main fracture at rear surface (a); with separation of final blocks (b); with the tool before its sinking into a blasthole (c); cross-section of a block at the moment of its detachment from a rock mass (d): *1*—front surface; *2*—crack in a bed; *3*—blast hole row at the rear surface; *4*—blasthole row at the end surface, *5*—end surface; *6*—working blasthole; *7*—tool; *8*—end crack; *9*—tool before immersion; *10*—the main crack; *11*—a final block; *12*—taper flange; *13*—flattened surface; d, d_1, α—tool parameters.
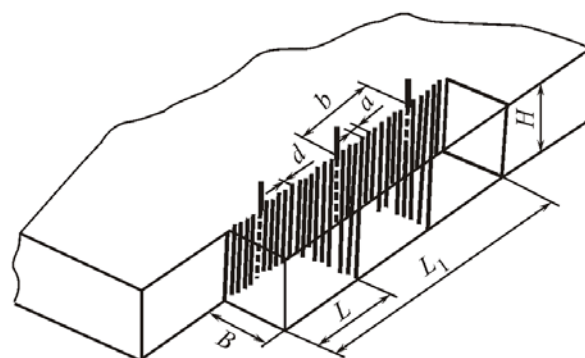

Figure 2. Prime process parameters of block preparation for separation from a rock mass.

When selecting parameters of a production area (H, B, L_1) it is imperative to consider a location of natural fractures (stratal, vertical, longitudinal, and transverse) which split a rock mass into discrete natural joints. The maximum size L of a final block does not usually exceed 2.8 m, its width B and height H are no more than 2 m [4]. Parameters of idle blasthole rows (d, a, h) are determined considering specifications of drill units and rock strength. In production of stone blocks the line drill units are employed to make blast holes of $d = 0.032$–0.042 m, a recommended spacing of drilling is a

= 0.1–0. m for granite depending on mechanical characteristics, length of blastholes should match a bench height ($h = H$). As for the process under consideration, it is necessary to determine a pitch of tool installation b and impact load parameters (A_{ed}, n).

Coefficient $Q = zd / S$, where z is total length of blastholes in the plane of splitting; d is blasthole diameter; S is area of block separation. In [6] it is experimentally proved that in the case when a single tool works in a rock mass from the central blasthole, a directed split-off takes place at coefficient $Q \geq 0.12–0.16$. The threshold ratio of length and width of a block to be separated is established ($L/B < 5$). Given that this ratio is not satisfied, a radial fracture (fault) tends to originate with orientation from the front surface of a bench to a point of impact load application. To provide a wanted split-off of a block and to eliminate formation of a radial fracture in a monolith under penetration of a single tool in the central blasthole, we select width of a block $B = 1.8$ m and $L_1 < 9$ m, respectively. It is reasonable to take length of working area L_1 be multiple of length of blocks, thus, at $L = 2.8$ m L_1 should be 8.4 m.

An experiment on granite oversize block imitating a working bench in a rock mass at scale of $1:5.75$ is undertaken to determine parameters of impact load (A_{ed}, n) and length l of the main crack induced under penetration of the tool. A block of $B \times H \times L = 1.5 \times 0.26 \times 0.45$ m in size was separated from the experimental oversize (Figure 3). At the prescribed split-off surface a line of blastholes ($d = 0.008$ m, $a = 0.05$ m) was drilled; the working tools are installed at pitch $b = 0.5$ m. The tool parameters are $d = 0.008$ m, $d_1 = 0.010$ m, $\alpha = 10°$(Figure 1c).
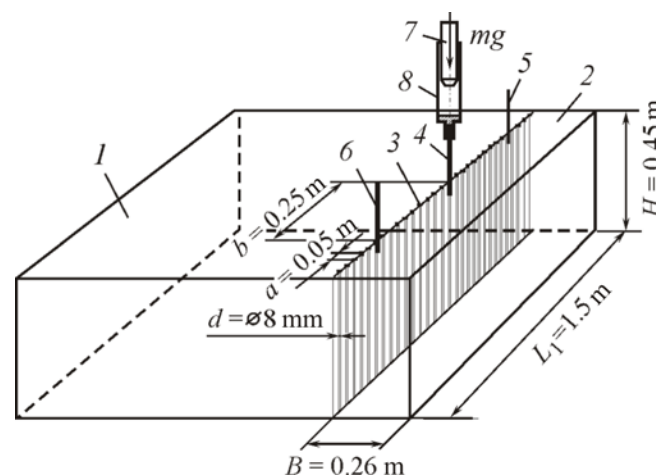

Figure 3. Scheme of physical modeling of block separation from a rock mass: *1*—section of granite oversize suggested as a rock mass, *2*—block to be separated, *3*—line of blastholes, *4–6*—tools, *7*—impact device, *8*—guide device.

First, tool *4*, mounted in the central blasthole, was sunk by impacts, then tools *5, 6* followed in succession. Impacts against the tools were performed with a certain energy by means of throwing an impact device of 20 kg in mass along a guide line from height of 0.2–0.46 m. Penetration x of the tool into a blasthole, an induced fresh fracture, fracture length l along a line of blastholes, and fracture opening δ in the tool zone were measured after every or few impacts.

According to the physical modeling results (Table 1, Figure 4) it is obvious that the impact energy should be increased with growth of an induced crack, thereto, crack formation and its growth are stepwise in character and depend on a magnitude of crack edge opening (Figure 5). To provide penetration of the central tool the required impact energy was A_{ed} =90 J, accumulated energy was $A_{(4)}$ =$A_{ed(4)}$ J; $n = 2310$; for tools *5* and *6*, J: $A_{ed(5)} = A_{ed(6)}$ =40, $A_{(5)}$=660, $A_{(6)}$ =560.

Table 1. Parameters of physical modeling of block separation from a rock mass.

| n	A_{ed}, J	A, J	x, mm	l, m	δ_1, mm	Notes
						Penetration of the central tool *4* (Figure 3)
			0	0		—
1–2	40	80	4	0	—	—
3–5	40	200	10	–"–	—	—
6	40	240	12	0.3	0.1	Initial fracture
7	40	280	14	–"–	0.1	—
8	40	320	16	–"–	0.2	—
9–16	35	600	36	–"–	0.3	Notable withdrawal of the impact device
17–21	90	1050	42	–"–	0.6	—
22	90	1140	44	0,6	0.7	—
23–24	90	1320	45.5	0.6	0,8	—
25	90	1410	46	0.7	0.9	—
26–34	90	2220	49	0.7	1.5	—
35	90	2310	52	0.8	1.7	—
						Penetration of tool *5* (Figure 3)
			0	0		—
1	20	20	3	0.1	0.1	Initial fracture
2–10	20	200	20	–"–	0.2	—
11	20	220	23	0.22	0.2	—
12–14	20	280	31	0.22	0.3	Extension of the fracture to end surface
15	20	300	33	0.5	0.3	Fracture length at the end surface - 300 mm
16–25	40	700	53	–"–	—	–"– 400 mm
26–35	40	660	63	–"–	—	–"– 440 mm
						Penetration of tool *6* (Figure 3)
			0	0		—
1–2	40	80	7	0	—	—
3	40	120	9	0,05	0,1	Initial fracture
4–9	40	360	26	–"–	0.2	—
10	40	400	30	0,5	0.3	Extension of the fracture to end surface
11–14	40	560	40	–"–	0.4	Fracture length at the end surface 440 mm (Figure 4d)
Disintegration	—	—	—	—	—	Mechanical retraction of a block (Figure 4f)
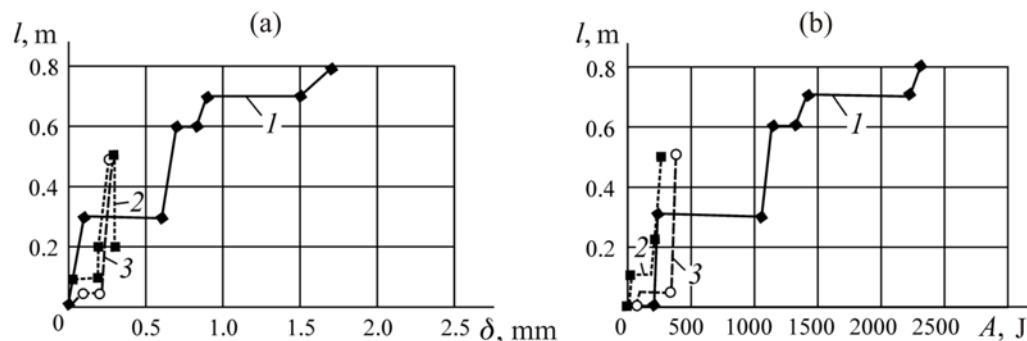
Figure 4. Main crack formation along blasthole line: (a)—dependence of crack length vs. crack edge opening in a blasthole with a tool; (b)—dependence of crack length vs. accumulated energy of impacts (*1*—fracture induced under penetration of the central tool *4*; *2*, *3*—cracks induced under penetration of side tools *5*, *6*).
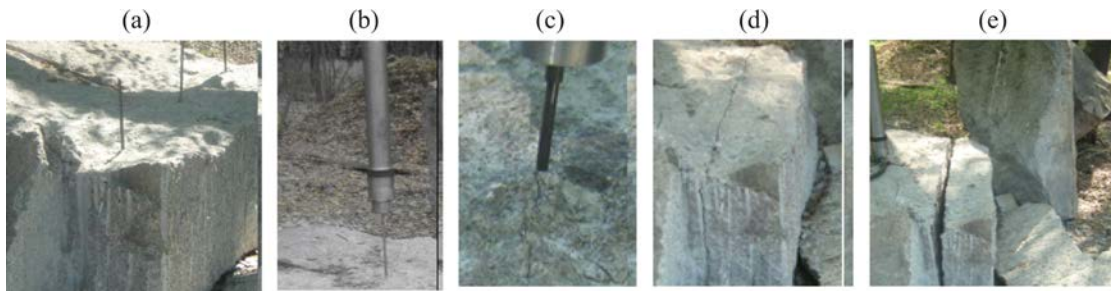
Figure 5. Separation of a granite block: (a)—installation of downhole tools; (b)—mounting of an impact device on the tool *4*; (c)—the initial crack formation induced by the central tool; (d)—crack length of 400 mm at the end surface under penetration of the tool *5*; (e)—resultant block separation.

Considering the principles of geometric and dynamic similarity [7], we determine basic parameter values for a real block separation at an actual open pit section. Geometric scale of modeling is $a = B_{nat} / B_{mod} = 1.5 / 0.26 = 5.77$, where B_{nat}, B_{mod} is width of a block to be separated in the real open pit and in the model. The scale of impact energy is $\varepsilon = A_{nat} / A_{mod} = m_{nat} / m_{mod} = a^3 = 192.1$, where A_{nat}, A_{mod} are energy of a single impact of a commercial and modeled hammer; m_{nat}, m_{mod} are mass of impact devices of a commercial and modeled hammers. In view of the above, the process parameters of rock-mass preparation to separate blocks are as follows: H—2.9 m, B—1.5 m, L_1—8.6 m, L—2.9 m, d—46 mm, h—2.6 m, a—0.29 m, b—2.9 m. Energy of a single impact is $A_{ed(4)}$—17.1 kJ for the central tool, $A_{ed(5,6)}$—7.6 kJ for the side tools, accumulated energy of impacts, kJ: $A_{(4)}$—439.1; $A_{(5)}$—125.5, $A_{(6)}$—106.5.

3. Conclusions

The process diagram is proposed to separate large-size granite blocks from a rock mass by impact punching with wedge tools providing an admissible opening of crack edges in the zone nearby a blasthole and excluding exposure of the main crack at the front surface of a bench.

The physical modeling method is implemented to determine a range of impact energy, applied to the tool; a pitch of the tool installation in the process of monolith separation is determined.

It is demonstrated that the required impact energy should be increased with growth of a crack; formation of a crack and its growth are stepwise in character and depend on a level of crack edge opening and the accumulated impact energy.

References

[1]   Tkachuk KK and Grebenyuk TV 2012 Stone block splitting off with static load Problems of subsoil use Proc. International Forum-Competition of Young Scientists Part 1 Saint-Petersburg pp. 82–85 (in Russian)

[2]   Kokunina LV 2007 The quality of competent rock blocks mined with a drill-and-wedge method Extraction, processing and application of natural stone Collection of scientific papers Magnitogorsk: MSTU No 7 pp 102–108 (in Russian)

[3]   Pershin GD and Pshenichnaya EG 2004 Substantiation of the effective expansion work of non-explosive demolition agents in the spur mining of block stones Extraction Processing and Application of Natural Stone Magnitogorsk: MSTU No 4 pp 70–79

[4]   Karasyov YuG and Bakka NT 1997 Natural stone Extraction of block and wall stone Tutorial Saint-Petersburg: SPGU (in Russian)

[5]   Pat. 124922 2013 Russian Federation Utility Model, Device for the formation of directional cracks in the boreholes (variants), Tambovtsev PN Pub date 2013/02/20 *Bull.* No 5

[6]   Tambovtsev PN 2015 Physical simulation of stone block cutting under impact action on plastic substance in drill hole Journal of Mining Science Vol 51 No 1 pp 73–80

[7]   Alabuzhev PM, Geronimus VB, Minkevich LM et al 1968 Theory of similarity and dimensions Modeling Moscow: Vysshaya Shkola (in Russian)