DOI: 10.21440/0536-1028-2020-2-25-36

Investigating the seismic impact made by the underground large-scale blast on the secure facilities of Kyshtym GOK when caving the floor pillar

Vyacheslav A. Kutuev[1]
[1] Institute of Mining UB RAS, Ekaterinburg, Russia
e-mail: slavik1988@mail.ru

Abstract

Introduction. *Within the mining claim boundaries of Kyshtym GOK the underground large-scale blast was made to cave in the floor pillar with the maximum explosive weight of 963 kg at the spacing stage. The Institute of Mining UB RAS has received a task to study the seismic impact of the underground large-scale blast on the secure facilities of Kyshtym underground mine industrial site located in the close proximity to the sites of blast works.*

Research aim *is to determine the seismic stability of grounds at the sites of the secure facilities and the permissible values of vibration velocities for Kyshtym GOK buildings. It is also necessary to determine the permissible distances from the blast to the secure facilities for 5 engineering-geological elements on the basis of physical and mechanical properties of rock.*

Research methodology. *On the basis of the initial data, according to the method of IM UB RAS, ground seismic stability calculations have been made at the sites of the facilities to determine the permissible values of vibration velocities for Kyshtym GOK buildings. A multivariate calculation of permissible distances from the blast to the secure facilities for 5 engineering-geological elements (EGE) has also been made depending on the explosive weight at the spacing stage, the coefficient of ground conditions and the permissible velocity of seismic vibrations.*

Results. *The actual velocities of earthquake vibrations were determined by the results of experimental measurements using Minimate Plus and URAN seismic recorders, the values of which did not exceed the permissible velocities of ground motion in the base of buildings.*

Summary. *As a result of comparing calculated values and experimental measurements, the recommendations have been given to establish the limitation of the explosive weight at the spacing stage to the level of minimum hazardous values during the large-scale blasts in the underground mine.*

Key words: *blasting; parameters of drilling and blasting; explosive materials; explosives; means of initiation; secure facilities; seismic impact of a blast; velocity of seismic ground motions; measures on seismic safety technology of blasting.*

Acknowledgements. *The research has been carried out within the framework of the State Proposal No. 075-00581-19-00, themes No. 0405-2019-0005 (2019–2021) as well as with additional attraction of contractual means.*

The following employees of Institute of Mining of Ural Branch of RAS have also participated in this work: Sergey N. Zharikov, Head of the Rock Destruction Laboratory; Pavel V. Menshikov, Junior Researcher of the Rock Destruction Laboratory; Alexander S. Flyagin, Junior Researcher of the Rock Destruction Laboratory.

Introduction. Within the boundaries of the mining allotment of *Kyshtym GOK (Kyshtym ore enrichment plant, JSC)* the underground large-scale blast have been made to break the floor pillar with the maximum explosive weight of 963 kg at the spacing stage. The Institute of Mining UB RAS has received a task to study the seismic impact

Fig. 1. Site plan of the Kyshtym deposit of granulated quartz
Рис. 1. Ситуационный план Кыштымского месторождения гранулированного кварца

of the underground large-scale blast on the secure facilities of Kyshtym underground mine industrial site located in the close proximity to the sites of blast works, namely: buildings of the sizing plant, main fan unit, and mining administration of Kyshtym GOK.

The blast works were carried out close to the earth's surface in close proximity to industrial secure facilities of Kyshtym underground mine industrial site.

Research aim is to determine the seismic stability of grounds at the sites of the secure facilities and the permissible values of vibration velocities for Kyshtym GOK buildings. It is also necessary to determine the permissible distances from the blast to the secure facilities for 5 engineering-geological elements on the basis of physical and mechanical properties of rock.

Brief mining and geological characteristics of the deposit. The deposit of granulated quartz is located in the Kyshtym district of the Chelyabinsk region, 30 km west of the Kyshtym railway station of the South Ural railway and stretches in the form of a narrow (1–3 km) submeridional strip by 22 km from Lake Agordyash in the south to mount Sharabrina in the north (fig. 1). The cities of Kyshtym, Kasli, Karabash, Verkhny Ufaley are located by 15, 50, 25 and 50 km from the deposit respectively.

Mountain landscape characterized by the development of low north-eastward directed mountains with low-angle inclination is typical for the Middle Urals.

Kyshtym deposit is currently the only major deposit of granulated quartz in Russia. Lode 175 is deposit's largest lode containing 90% of the granular quartz reserves discovered and approved in the State Reserves Committee of the USSR. The qualitative characteristics of quartz meet the requirements of consumer plants.

The lode is formed by granular quartz of fine-grained granoblastic structure with 1–2 mm grain size. Average mineral composition of the lode rock according to prospecting data is as follows: quartz – 95%, chats – 5%. The latter are represented by coarse-grained amphibole and biotite 5–50 cm thick, by folia of gneissogranite and pegmatite 0.05–2.0 m thick, lenses of carbonate-plagioclase and carbonate composition 0.05–0.5 m thick.

The host rocks are represented by biotite-amphibolic gneisses, granite-gneisses, and pegmatites (table 1).

Two main cracking systems are observed in the area of the lode. The first system: strike azimuth of 30°–40°, subvertical dip angles (80°–90°). The second system: strike azimuth of 210°–230°, dip angle of 60°–80°.

The average jointing is 0.5–1 cracks per linear meter. All the observed cracks, usually closed, are often cemented by later minerals: feldspar and pegmatites. Large-scale tectonic disturbances within the site have not been recorded.

Research methods. Dynamics of blast effect manifests in earthquake vibrations of the ground. The permissible seismic impact by large-scale blasts is determined in two directions. First, the impact of earthquake vibrations caused by blasting must not lead to rock mass within destabilization within the facility site. Second, the ground vibrations under the construction (building) at the site must not lead to the destruction of foundations and structures. To perform a complex of ground seismic stability calculations at the sites of the facilities and to determine the permissible values of vibration velocity for buildings of Kyshtym GOK, the inventions of IM UB RAS have been used (*Methods of IM UB RAS no. 88-16359-118-01.00076-2011. (In Russ.); Method of providing seismic safety technology for blast works. Sverdlovsk: IM MISI USSR Publishing; 1984. (In Russ.)*), [1–5].

To determine the permissible value of the earthquake vibration velocity it is necessary to set the permissible stress in the rock mass. The permissible value of stresses is in accordance with the mine seismic stability condition:

$$[\sigma_{st}] + [\sigma_{dyn}] \le \sigma_{extra}, \quad (1)$$

where $[\sigma_{st}]$ – static stress in the rock mass surrounding the mine, MPa; $[\sigma_{dyn}]$ – dynamic stress in the rock mass (near the mine), MPa; σ_{extra} – permissible value of stresses, MPa.

Table 1. Physical and mechanical properties of quartz and host rocks of lode no. 175
Таблица 1. Физико-механические свойства кварца и вмещающих пород жилы № 175

Ore and rock	Volume mass, t/m^3	Hard ness ratio	Compres sion strength, MPa	Poisson coeffici ent	Wave velocity, m/s		Jung modulus, $E \cdot 10^{-3}$ MPa	Acoustic stiffness, $A \cdot 10^{-3}$ MPa
					longitu dinal	trans verse		
Homogeneous quartz	2.67	10–15	113–178	0.27	5500	3200	115	0.143
Quartz intergrowths	2.60	5–8	54–92	0.27	5375	2900	112	0.146
Pegmatites	2.74	8–10	110	0.26	4550	3000	124	0.144
Amphibolic biotite	2.60	8–10	152	0.24	4837	2487	95.7	0.112
Granite gneiss	2.73	8–10	166	0.25	4540	2540	104	0.123

In simplistic terms, rock static tensile strength σ_t in the rock mass increased by 10–30% [3] can be taken as the permissible value of stresses σ_{extra}. It should be noted that σ_t determined in the sample differs significantly from the value in the rock mass due to macrodisturbances. In the rock mass σ_t is 5–10 and more times as high as in the sample [1], because rocks are usually mixed together; this value is also significantly affected by jointing and voids filler. The tensile strength of the rock mass is determined by means of the coefficient of structural weakening. In some cases, an approximate calculation is possible based on the average coefficient of structural weakening and strength certificate.

According to [1], the permissible velocity of the rock mass displacement can be determined by the expression:

$$v_{extra} = \frac{2\sigma_{extra}}{\gamma C} \cdot 981 \cdot 10^3, \mathrm{cm/s}, \quad (2)$$

where σ_{extra} – the permissible value of stresses, kgf/cm^2; γ – the density of rocks, t/m^3; C – rock acoustic velocity, cm/s.

Taking into acount the actual measured data, the above expression (2) can be expressed in terms of the indicator values in the SI system in the following form:

$$v_{extra} = \frac{\sigma_{extra}}{\gamma C} \cdot 2604.1, \ \mathrm{m/s}, \quad (3)$$

where σ_{extra} – the permissible value of stresses, MPa; γ – density of rocks, t/m^3; C – rock acoustic velocity, cm/s.

The velocity of earthquake vibrations depending on the weight of explosives in the stage and the distance from the blast to the secure facility can be determined according to [1] by the following expression (if the distance to the object is less than 1500 m):

$$v = K\sqrt{\frac{Q}{R^3}}, \text{ cm / s}, \tag{4}$$

where v – the velocity of earthquake vibrations, cm/s; Q – weight of simultaneous shots (weight of explosives at the spacing stage), kg; R – the distance to the object, m; K – the coefficient depending on ground conditions (rocky and semi-rocky grounds $K = 200–300$; sand-clay grounds $K = 300–450$; loose, watered, and filled grounds $K = 450–600$.

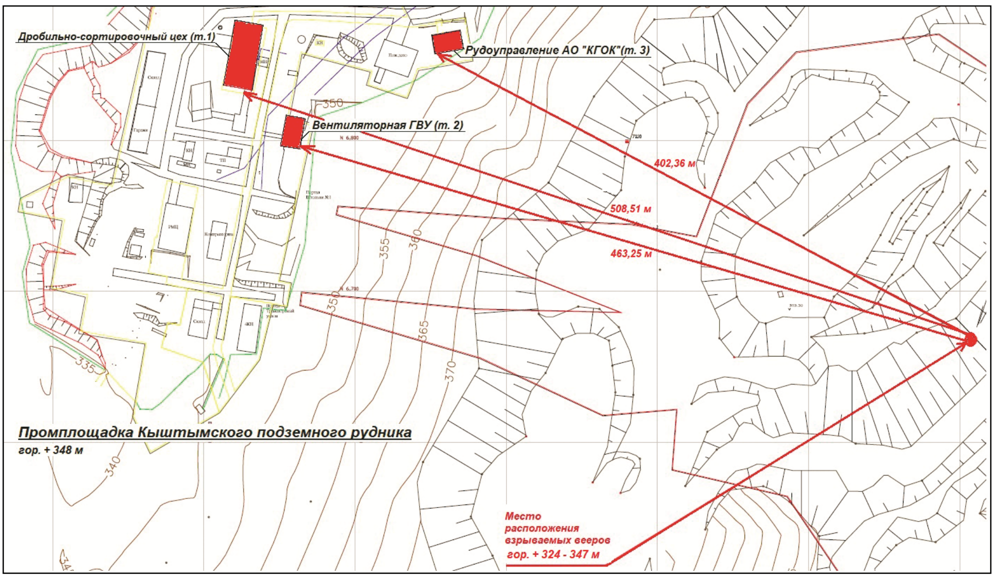

Fig. 2. Location points of blasthole ring (1-P) with maximum explosive weight per the stage at the mine and at the secure facilities (1, 2, 3) of Kyshtym GOK
Рис. 2. Точки местоположения взрываемых вееров скважин (1-Р) с максимальной массой ВВ в ступени на руднике и на охраняемых объектах (1, 2, 3) Кыштымского ГОКа

Thus, by determining the permissible velocity of vibrations of the protected area (expression (3)) and substituting the obtained value into expression (4), it is possible to determine, depending on the distance, the permissible weight of explosives per the spacing stage. Considering that currently the explosive devices can provide independent operation of each charge of explosives in the borehole, such calculations make it possible to optimize the parameters of drilling and blasting and to significantly reduce the seismic impact of the blast on the protected rock mass and facilities.

Distances at which the ground vibrations caused by a single blast of the concentrated charge of explosives become safe for buildings and constructions according to the federal norms (*Federal norms and regulations in the field of industrial safety “Safety Rules during Blast Works”. Series 13. Issue 14. Moscow: Closed Joint Stock Company*

Table 2. Initial data and calculated values of seismic stability of grounds
Таблица 2. Исходные данные и расчетные значения сейсмоустойчивости грунтов

Rock	Density, t/m^3	Compression strength in sample, MPa	Tensile strength in sample, MPa	Poisson coefficient	Modulus of elasticity, GPa	Velocity of longitudinal waves in ground, m/s	Velocity of transverse waves, m/s	Accepted coefficient of structural weakening	Compression strength in rock mass, MPa	Tensile strength in rock mass, MPa	Accepted stress value, MPa	Permissible velocity of seismic vibrations of ground, m/s
Homogeneous quartz	2.67	178.0	17.80	0.27	115.0	5.500	3.087	0.15	26.70	2.67	3.47	0.62
	2.64	145.5	14.55	0.27	115.0	4.483	2.516	0.15	21.83	2.18	2.84	0.63
	2.60	113.0	11.30	0.27	115.0	3.465	1.945	0.15	16.95	1.70	2.20	0.64
Quartz intergrowths	2.60	92.0	11.50	0.27	112.0	5.375	3.017	0.30	27.60	3.45	4.49	0.84
	2.58	73.0	9.13	0.27	112.0	4.273	2.398	0.30	21.90	2.74	3.56	0.84
	2.55	54.0	6.75	0.27	112.0	3.171	1.780	0.30	16.20	2.03	2.63	0.85
Pegmatites	2.74	110.0	11.00	0.26	124.0	4.550	2.591	0.25	27.50	2.75	3.58	0.75
	2.62	98.0	9.80	0.26	124.0	4.050	2.306	0.25	24.50	2.45	3.19	0.78
	2.50	86.0	8.60	0.26	124.0	3.550	2.022	0.25	21.50	2.15	2.80	0.82
Amphibolic biotite	2.60	152.0	19.00	0.24	95.7	4.837	2.829	0.15	22.80	2.85	3.71	0.77
	2.57	143.5	17.94	0.24	95.7	4.566	2.671	0.15	21.53	2.69	3.50	0.78
	2.54	135.0	16.88	0.24	95.7	4.295	2.512	0.15	20.25	2.53	3.29	0.79
Granite gneiss	2.73	166.0	16.60	0.25	104.0	4.540	2.621	0.15	24.90	2.49	3.24	0.68
	2.67	156.0	15.60	0.25	104.0	4.266	2.463	0.15	23.40	2.34	3.04	0.70
	2.60	146.0	14.60	0.25	104.0	3.992	2.305	0.15	21.90	2.19	2.85	0.71

“Scientific and Technical Center for Industrial Safety Research”. 2014. (In Russ.)) are determined by the formula:

$$R_c = K_g K_c \alpha \sqrt[3]{Q}, \text{m}, \quad (5)$$

where R_c – the distance from the blast site to the protected building (construction), m; K_g – the coefficient depending on the ground properties in the base of the protected building (construction); K_c – the coefficient depending on the type of building (construction) and the pattern of buildings; α – the coefficient depending on blasting conditions; Q – the weight of the charge, kg.

Table 3. Characteristic of secure facilities and calculation of permissible velocity of seismic vibrations

Таблица 3. Характеристика охраняемых объектов и расчет допустимой скорости сейсмических колебаний

Parameters	Secure facilities – industrial buildings and constructions		
	Three-storey building of the sizing plant of Kyshtym GOK – point 1	Two-storey building of main fan unit of Kyshtym GOK – point 2	Two-storey building of the mining administration of Kyshtym GOK – point 3
	Industrial buildings and constructions in plan of no more than three storeys with small crowded area		
Facility state	Absence of any disturbances and residual deformations	There are small cracks in the foundation and filler	
Type of ground	Thin leveled screed of solid slab foundation		
Type of construction	Mining building		Business building
Main material of construction	Steel, reinforced concrete	Brickwork, concrete slabs	Reinforced concrete
Foundation type	Solid foundation		
Distance between the vibration source and measuring point	More than 200 m		
Vibration source type	Blast works		
F_g	2.5	2.5	2.5
k_b	1.2	1.2	1.2
k_m	1.2	1.0	1.2
k_f	0.8	0.8	0.8
F_d	1.0	1.0	1.0
F_k	1.0	1.0	1.0
Limit value of short-term vibration, cm/s (mm/s)	5.76 (57.6)	4.8 (48)	5.76 (57.6)

It should be noted that expression (5) does not take into account the specificity of geological conditions in the area of the mine, which is expressed in the enhanced seismic impact of water-saturated loose rock and hard rock. The values are highly underestimated and present a distorted picture in drilling and blasting parameters determination near the secure facilities.

To reduce determination errors, the permissible distances R for the complex can be determined by converting expression (4):

Table 4. Results of instrumental measurements and design parameters of seismic vibrations
Таблица 4. Результаты инструментальных замеров и расчетных параметров сейсмических колебаний

Facility	Facility point number	Mine point number	The shortest distance from the mine to the secure facility, m	Maximum weight of simultaneously blast charge of explosives per stage, kg	Permissible velocity of seismic vibrations of unbuilt ground, m/s	Coefficient of ground conditions K	Hazardous weight of explosives per spacing stage for sloping and ground constructions, kg	Actual velocity of seismic vibrations, m/s				Permissible maximum velocity of seismic vibrations of the ground in the base of buildings, m/s	Hazardous weight of explosives per spacing stage for buildings, kg
								Longitudinal wave V_x	Transverse wave V_y	Vertical wave V_z	Resulting V		
Sizing plant	1	1 - P	508	963	0.06	200	118.343	–	–	–	–	0.0576	109.065
						300	52.597						48.473
						450	23.376						21.544
Main fan unit	2		463			200	89.472	0.001	0.001	0.0028	0.0031	0.048	57.262
						300	39.765						25.450
						450	17.674						11.311
Mining Administration of AO Kyshtym GOK	3		402			200	58.626	0.0005	0.0006	0.0009	0.0012	0.0576	54.029
						300	26.056						24.013
						450	11.580						10.672

$$R = \sqrt[3]{\frac{K^2 Q}{v_{extra}^2}}, \text{ m}, \quad (6)$$

where v_{extra} – the permissible velocity of seismic ground vibrations, cm/s; Q – the mass of simultaneous (instant) shots, kg; R – the distance to the blast site, m; K – the coefficient depending on the ground conditions at the base of constructions.

For ground motion in the base of buildings and constructions according to the GOST (*GOST R 52892-2007. Vibration and Strike. Vibration of Buildings. Measurement of Vibration and Evaluation of its Impact on Construction. (In Russ.)*), the limit value V for short-term vibration is determined for the vertical component of velocity peak value:

$$V = V_0 F_g F_b F_d F_k, \text{ mm / s}, \quad (7)$$

where V_0 – reference velocity equal to 20 mm/s; F_g – correction for ground type at the site where the construction is installed; F_b – correction for the construction type; F_d – correction for the distance between the vibration source and the measuring point; F_k – correction for the vibration source type.

Thus, the presented problem solution allows to make preliminary calculations, assess the possible impact of blasting on the secure facility and make appropriate technical solutions to mining.

Results. Based on the initial data, the blasting force impact on the grounds and constructions of Kyshtym GOK has been calculated and the permissible vibration velocity has been compared with the calculated one (see table 2). The table's data show that the rock mass has a fairly high seismic resistance (marked in table 2 in green). The permissible velocity for seismically active areas (magnitude 6–7) is equal to 0.06 m/s.

The necessary initial data for seismic stability calculation have not been fully provided in the given geological materials. Therefore, part of the data has been taken from reference literature [6–12].

For further calculations the points have been selected at the mine (point 1-P) as well as at the secure facilities (points 1, 2, 3) of Kyshtym GOK (fig. 2). At these points, the earthquake vibrations have been measured using Minimate Plus seismic recorder (Instantel, Canada, St. Ontario) and two seismic recorders URAN (Enterprise Horizon, Russia, Ekaterinburg) with GS-20 seismic receivers mounted in the ground on different sides of the blasted block and oriented in three directions relative to the blast.

Seismic stability calculations have been made for the secure facilities of Kyshtym GOK according to the GOST (*GOST R 52892-2007. Vibration and Strike. Vibration of Buildings. Measurement of Vibration and Evaluation of its Impact on Construction. (In Russ.)*) and summarized in table 3.

According to the selected points and taking the average values of the permissible velocity of ground motion v_{extra} = 0.06 m/s, and at the base of the buildings: sizing plant – 0.0576 m/s, main fan unit – 0.048 m/s, mining administration of Kyshtym GOK – 0.0576 m/s, with the average coefficient of ground conditions K = 300 the calculations have been made, as shown in table 4.

Summary. When blasting to cave the floor pillar at the Kyshtym underground mine, the values of ground seismic vibrations maximum resulting velocity were the following: near the foundation of the two-storey building of main fan unit – 0.0031 m/s and near the two-storey building of mining administration – 0.0012 m/s, which are less than the permissible velocity of ground vibrations in the base of buildings. During the underground large-scale blast when caving the floor pillar, the seismic recorder URAN did not register ground seismic vibrations velocity near the three-story building of the sizing plant of Kyshtym GOK, since the actual velocity was below the sensitivity threshold of the GS-20DX seismic sensors.

Dynamic calculation analysis has been performed for blasting force impact on grounds and buildings of Kyshtym GOK facilities. Since the calculation has been performed in variants, it is recommended to set limits on the weight of explosives at the level of minimum hazardous values.

The hazardous weight of explosives blasted in the mine at the same time for sloping and ground constructions of Kyshtym GOK facilities is as follows:

– sizing plant – 52 597 kg;
– main fan unit – 39 765 kg;
– mining administration of Kyshtym GOK – 26 056 kg.

The hazardous weight of explosives blasted in the mine at the same time for buildings of Kyshtym GOK facilities:

– sizing plant – 48 473 kg;
– main fan unit – 25 450 kg;
– mining administration of Kyshtym GOK – 24 013 kg.

Enterprise Protol has performed the blast works when caving the floor pillar at the Kyshtym underground mine by ensuring the safety of seismic impact made by the underground large-scale blast, and these blast works do not have a negative impact on the building of the sizing plant, the buildings of the main fan unit and the mining administration of Kyshtym GOK.

REFERENCES

1. Zharikov S. N., Shemenev V. G. On the effect of blasting on stability of pit barriers. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = News of the Higher Institutions. Mining Journal*. 2013; 2: 80–83. (In Russ.)

2. Zharikov S. N., Shemenev V. G. On the influence of blasting on the stress state of rock mass and geodynamic phenomena. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = News of the Higher Institutions. Mining Journal*. 2013; 3: 90–97. (In Russ.)

3. Bondarenko I. F., Zharikov S. N., Zyrianov I. V., Shemenev V. G. *Blast works at kimberlite open-pits of Yakutia*. Ekaterinburg: IM UB RAS; 2017. (In Russ.)

4. Shemenev V. G., Zharikov S. N. On the state of scientific researches in the field of rocks destruction in the Institute of Mining UB RAS. *Problemy nedropolzovaniia = The Problems of Subsoil Use*. 2016; 4(11): 30–40. (In Russ.)

5. Zharikov S. N., Kutuev V. A. The study of the seismic effect of the explosion in the quarry for the introduction of a special technology of work on the formulation of the boards in the limit position. In: *Deep structure, geodynamics, thermal field of the earth, interpretation of geophysical fields: conference materials*. 2017: 179–183. (In Russ.)

6. Protodiakonov M. M., Teder R. I., Ilnitskaia E. I., et al. *Distribution and correlation of physical properties of rocks*. Moscow: Nedra Publishing; 1981. (In Russ.)

7. Protodiakonov M. M., Teder R. I., Ilnitskaia E. I., et al. *Reference (cadastre) of physical properties of rocks*. Moscow: Nedra Publishing; 1975. (In Russ.)

8. Rzhevskii V. V., Novik G. Ia. *Fundamentals of physics of rocks*. Moscow: Nedra Publishing; 1984. (In Russ.)

9. Rzhevskii V. V. *Physical and technical parameters of rocks*. Moscow: Nauka Publishing; 1975. (In Russ.)

10. Chukhrov F. V. (ed.) *Minerals. Reference book. In 4 vol*. Moscow: AS USSR Publishing; 1992. (In Russ.)

11. Dortman N. B. (ed.) *Physical properties of rocks and minerals (petrophysics). Handbook of geoscientist.* Moscow: Nedra Publishing; 1984. (In Russ.)

12. Drukovanyi M. F. *Methods of blast control in open-pit mines*. Moscow: Nedra Publishing; 1973. (In Russ.)

Received 14 August 2019

Information about authors:

Vyacheslav A. Kutuev – researcher, Institute of Mining UB RAS. E-mail: slavik1988@mail.ru

УДК 622.235.535.2 DOI: 10.21440/0536-1028-2020-2-25-36

Исследование сейсмического воздействия подземного массового взрыва на охраняемые объекты Кыштымского ГОКа при обрушении межэтажного целика

Кутуев В. А.[1]
[1] Институт горного дела УрО РАН, Екатеринбург, Россия.

Реферат

Введение. *В пределах границ горного отвода АО «Кыштымский ГОК» произведен подземный массовый взрыв по обрушению межэтажного целика с максимальной массой взрывчатых веществ в ступени замедления 963 кг. Институту горного дела УрО РАН была поставлена задача по изучению сейсмического влияния подземного массового взрыва на охраняемые объекты промплощадки Кыштымского подземного рудника, находящиеся в непосредственной близости от мест ведения взрывных работ.*

Целью работы *является определение сейсмоустойчивости грунтов на площадках охраняемых объектов и допустимых значений скоростей колебаний для зданий АО «Кыштымский ГОК». Также необходимо на основе физико-механических свойств пород месторождения определить допустимые расстояния от взрыва до охраняемых объектов для пяти инженерно-геологических элементов.*

Методология исследований. *На основании исходных данных по методике ИГД УрО РАН выполнен комплекс расчетов сейсмоустойчивости грунтов на площадках объектов и определены допустимые значения скоростей колебаний для зданий АО «Кыштымский ГОК». Также произведен многовариантный расчет допустимых расстояний от взрыва до охраняемых объектов для пяти инженерно-геологических элементов (ИГЭ) в зависимости от массы ВВ в ступени замедления, коэффициента грунтовых условий и допустимой скорости сейсмических колебаний.*

Результаты. *Установлены фактические скорости сейсмических колебаний по результатам экспериментальных замеров с применением сейсморегистраторов Minitate Plus и УРАН, значения которых не превысили допустимых скоростей колебаний грунта в основании зданий.*

Выводы. *В результате сравнения расчетных значений и экспериментальных замеров даны рекомендации по установлению ограничения массы ВВ в ступени замедления на уровне минимальных опасных значений при проведении массовых взрывов в подземном руднике.*

Ключевые слова: *взрывные работы; параметры буровзрывных работ; взрывчатые материалы; взрывчатые вещества; средства инициирования; охраняемые объекты; сейсмическое действие взрыва; скорость сейсмических колебаний грунта; мероприятия по сейсмобезопасной технологии взрывных работ.*

Исследования выполнены в рамках Государственного задания № 075-00581-19-00, тема № 0405-2019-0005 (2019–2021 гг.), а также при дополнительном привлечении хоздоговорных средств. В работе приняли участие сотрудники Института горного дела Уральского отделения РАН: Жариков Сергей Николаевич, заведующий лабораторией разрушения горных пород; Меньшиков Павел Владимирович, младший научный сотрудник лаборатории разрушения горных пород; Флягин Александр Сергеевич, младший научный сотрудник лаборатории разрушения горных пород.

БИБЛИОГРАФИЧЕСКИЙ СПИСОК

1. Жариков С. Н., Шеменев В. Г. О влиянии взрывных работ на устойчивость бортов карьеров // Известия вузов. Горный журнал. 2013. № 2. С. 80–83.

2. Жариков С. Н., Шеменев В. Г. О влиянии взрывных работ на напряженное состояние горного массива и геодинамические явления // Известия вузов. Горный журнал. 2013. № 3. С. 90–97.

3. Бондаренко И. Ф., Жариков С. Н., Зырянов И. В., Шеменев В. Г. Буровзрывные работы на кимберлитовых карьерах Якутии. Екатеринбург: ИГД УрО РАН, 2017. 172 с.

4. Шеменев В. Г., Жариков С. Н. О состоянии научных исследований в области разрушения горных пород в Институте горного дела УрО РАН // Проблемы недропользования. 2016. № 4(11). С. 30–40.

5. Жариков С. Н., Кутуев В. А. Изучение сейсмического действия взрыва в карьере для внедрения специальной технологии заоткосных работ // Глубинное строение, геодинамика, тепловое поле Земли, интерпретация геофизических полей: матер. Всерос. конф. с междунар. участием. 2017. С. 179–183.

6. Распределение и корреляция показателей физических свойств горных пород / М. М. Протодьяконов [и др.]. М.: Недра, 1981. 192 с.

7. Справочник (кадастр) физических свойств горных пород / ред. Н. В. Мельников [и др.]. М.: Недра, 1975. 279 с.

8. Ржевский В. В., Новик Г. Я. Основы физики горных пород. М.: Недра, 1984. 359 с.

9. Ржевский В. В. Физико-технические параметры горных пород. М.: Наука, 1975. 212 с.

10. Минералы. Справочник в IV т. / ред. Ф. В. Чухров. М.: АН СССР, 1992.

11. Физические свойства горных пород и полезных ископаемых (петрофизика). Справочник геофизика / ред. Н. Б. Дортман. М.: Недра, 1984. 455 с.
12. Друкованый М. Ф. Методы управления взрывом на карьерах. М.: Недра, 1973. 415 с.

Поступила в редакцию 14 августа 2019 года

Сведения об авторах:

Кутуев Вячеслав Александрович – научный сотрудник Института горного дела УрО РАН. E-mail: slavik1988@mail.ru

Для цитирования: Кутуев В. А. Исследование сейсмического воздействия подземного массового взрыва на охраняемые объекты Кыштымского ГОКа при обрушении межэтажного целика // Известия вузов. Горный журнал. 2020. № 2. С. 25–36 (In Eng.). DOI: 10.21440/0536-1028-2020-2-25-36
For citation: Kutuev V. A. Investigating the seismic impact made by the underground large-scale blast on the secure facilities of Kyshtym GOK when caving the floor pillar. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = News of the Higher Institutions. Mining Journal*. 2020; 2: 25–36. DOI: 10.21440/0536-1028-2020-2-25-36