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# N E W S
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*The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.*

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*Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.*

*ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.*

*Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.*

*Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.*

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*Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).*

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# ENGINEERING CONTROL OF BLAST-INDUCED SEISMICITY AND ENVIRONMENTAL SAFETY IN UNDERGROUND ORE MINING UNDER COMPLEX GEODYNAMIC CONDITIONS

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**Abstract.** *Relevance.* Underground mining of ore deposits in complex geodynamic conditions is accompanied by the accumulation of man-made stresses in the rock mass, leading to rock bursts and man-made earthquakes. The main source of induced seismicity is blasting, the parameters of which directly affect the stability of the rock mass and the safety of underground infrastructure. *Objective.* To quantitatively assess the impact of seismic blasting parameters on the deformation and stress state of the ore-bearing rock mass, establish critical levels of vibration velocities hazardous to underground structures, and substantiate the effectiveness of backfill and shielding masses as a means of reducing induced seismicity. *Methods.* A series of laboratory tests of core samples for uniaxial compression, in-kind seismic measurements in underground workings, and instrumental deformation monitoring were conducted. During the field experiments, the explosive mass per deceleration (200–900 kg), deceleration intervals (15–45 ms), and distances to recording points (5–80 m) were varied. The analysis included recording the horizontal and vertical components of oscillation velocities, calculating induced stresses, and assessing the effect of backfill masses with different grain size distributions on seismic wave attenuation. *Results.* It was established that the maximum oscillation velocities reach 0.7–0.9 m/s in the elastic-plastic deformation zone and exceed 1.0 m/s with increasing charge mass, which corresponds to the conditions for the formation of man-made seismic events. The horizontal component of oscillations exceeds the vertical one by 20–40% and has a decisive influence on the damage to the support structure. Increasing deceleration intervals to 30 ms reduces vibration velocities by 25–35%. Backfill arrays reduce stress at the seismic wave front by 2.5–3.5 times, with the greatest efficiency achieved using fine-grained and layered backfills. *Conclusions.* The obtained results confirm that managing blasting parameters and targeted use of backfill effectively reduce induced stress levels and seismic hazard during underground ore mining. The proposed approach enables a transition from reactive to proactive management of the geodynamic state of the rock mass and can be used in the design of safe and sustainable underground mining technologies.

**Key words:** man-made earthquakes, seismic explosive effects, particle oscillation velocity, mass stress state, underground ore mining, backfill massifs, seismic safety

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# ЖАРЫЛЫС ЖҰМЫСТАРЫНАН ТУЫНДАҒАН СЕЙСМИКАЛЫҚТЫ ИНЖЕНЕРЛІК БАҚЫЛАУ ЖӘНЕ КҮРДЕЛІ ГЕОДИНАМИКАЛЫҚ ЖАҒДАЙЛАРДА КЕНДІ ЖЕРАСТЫ ӨНДІРУ КЕЗІНДЕ ЭКОЛОГИЯЛЫҚ ҚАУІПСІЗДІКТІ ҚАМТАМАСЫЗ ЕТУ

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**Аннотация.** *Өзектілігі.* Күрделі Геодинамика жағдайында кен орындарын жерасты игеру тау жыныстары массивінде техногендік кернеулердің жинақталуымен қатар жүреді, бұл тау соққылары мен техногендік жер сілкіністерінің пайда болуына әкеледі. Индукцияланған сейсмиканың негізгі көзі жарылғыш заттар болып табылады, олардың параметрлері массивтің тұрақтылығына және жер асты инфрақұрылымының қауіпсіздігіне тікелей әсер етеді. *Мақсат.* Сейсмикалық жарылыс жұмыстарының параметрлерінің кенді массивтің деформациялық және кернеулі күйіне әсерін сандық бағалау, жер асты құрылыстары үшін қауіпті тербелмелі жылдамдықтардың сыни деңгейлерін белгілеу және индукцияланған сейсмикалықты төмендету құралы ретінде толтырғыш және скринингтік массивтердің тиімділігін негіздеу. *Әдістері.* Бір осьті қысуға арналған негізгі үлгілерді зертханалық сынау, жерасты қазбаларындағы табиғи сейсмикалық өлшеулер және деформациялардың аспаптық мониторингі кешені жүргізілді. Далалық эксперименттер кезінде жарылғыш заттардың массасы бір баяулауда (200-900 кг), баяулау аралықтары (15-45 мс) және тіркеу пункттеріне дейінгі қашықтық (5-80 м) өзгерді. Талдау тербеліс жылдамдығының көлденең және тік компоненттерін тіркеуді, индукцияланған кернеулерді есептеуді және сейсмикалық толқындардың ыдырауына әртүрлі гранулометриялық құрамдағы толтырғыш массивтердің әсерін бағалауды қамтыды. *Нәтижелер.* Тербелістердің максималды жылдамдығы серпімді–пластикалық деформация аймағында 0,7-0,9 м/с-қа жетеді және заряд массасының жоғарылауымен 1,0 м/с-тан асады, бұл техногендік сейсмикалық оқиғалардың қалыптасу шарттарына сәйкес келеді. Тербелістердің көлденең компоненті вертикальдан 20-40% - ға асады және бекіткіштің зақымдалуына шешуші әсер етеді. Баяулау аралықтарын ұлғайту. ***Қорытындылар.*** Алынған нәтижелер жарылыс жұмыстарының параметрлерін басқару және толтырғыш массивтерді мақсатты қолдану жерасты кендерін өндіру кезінде туындаған кернеулер мен сейсмикалық қауіптілік деңгейін тиімді төмендетуге мүмкіндік беретіндігін растайды. Ұсынылған тәсіл реактивті бақылаудан массивтің геодинамикалық күйін проактивті басқаруға көшуді қамтамасыз етеді және кен орындарын жерасты игерудің қауіпсіз және тұрақты технологияларын жобалау кезінде пайдаланылуы мүмкін.

**Түйінді сөздер:** техногендік жер сілкінісі, сейсмикалық жарылыс әсерлері, бөлшектердің тербеліс жылдамдығы, массивтің кернеу күйі, жер асты кендерін өндіру, жер қойнауын пайдалану, сейсмикалық қауіпсіздік

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# ИНЖЕНЕРНЫЙ КОНТРОЛЬ СЕЙСМИЧНОСТИ, ВЫЗВАННОЙ ВЗРЫВНЫМИ РАБОТАМИ, И ОБЕСПЕЧЕНИЕ ЭКОЛОГИЧЕСКОЙ БЕЗОПАСНОСТИ ПРИ ПОДЗЕМНОЙ ДОБЫЧЕ РУДЫ В СЛОЖНЫХ ГЕОДИНАМИЧЕСКИХ УСЛОВИЯХ

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**Аннотация.** *Актуальность*. Подземная разработка рудных месторождений в условиях сложной геодинамики сопровождается накоплением техногенных напряжений в массиве горных пород, что приводит к возникновению горных ударов и техногенных землетрясений. Основным источником индуцированной сейсмичности являются взрывные работы, параметры которых напрямую влияют на устойчивость массива и безопасность подземной инфраструктуры. *Цель*. Количественно оценить влияние параметров сейсмовзрывных работ на деформационное и напряжённое состояние рудоносного массива, установить критические уровни колебательных скоростей, опасные для подземных сооружений, и обосновать эффективность закладочных и экранирующих массивов как средств снижения индуцированной сейсмичности. *Методы*. Проведён комплекс лабораторных испытаний керновых образцов на одноосное сжатие, натурных сейсмических измерений в подземных выработках и инструментального мониторинга деформаций. В ходе полевых экспериментов варьировались масса взрывчатого вещества в одном замедлении (200–900 кг), интервалы замедления (15–45 мс) и расстояния до пунктов регистрации (5–80 м). Анализ включал регистрацию горизонтальных и вертикальных компонент скоростей колебаний, расчёт индуцированных напряжений и оценку влияния закладочных массивов различного гранулометрического состава на затухание сейсмических волн. *Результаты*. Установлено, что максимальные скорости колебаний достигают 0,7–0,9 м/с в зоне упруго-пластических деформаций и превышают 1,0 м/с при увеличении массы заряда, что соответствует условиям формирования техногенных сейсмических событий. Горизонтальная составляющая колебаний превышает вертикальную на 20–40% и оказывает определяющее влияние на повреждение крепи. Увеличение интервалов замедления до 30 мс снижает скорости колебаний на 25–35%. Закладочные массивы обеспечивают уменьшение напряжений на фронте сейсмической волны в 2,5–3,5 раза; при этом наибольшая эффективность достигается при использовании мелкозернистых и слоистых закладок. *Выводы*. Полученные результаты подтверждают, что управление параметрами взрывных работ и целенаправленное применение закладочных массивов позволяют эффективно снижать уровень индуцированных напряжений и сейсмическую опасность при подземной добыче руд. Предложенный подход обеспечивает переход от реактивного контроля к проактивному управлению геодинамическим состоянием массива и может быть использован при проектировании безопасных и устойчивых технологий подземной разработки месторождений.

**Ключевые слова:** техногенные землетрясения, сейсмовзрывные воздействия, скорость колебаний частиц, напряжённое состояние массива, подземная добыча руд, закладочные массивы, сейсмическая безопасность

**Introduction.** The global development of the mining industry in recent decades has been accompanied not only by increased mineral extraction volumes but also by increased man-made impacts on the geological environment. One of the most dangerous and difficult to predict manifestations of this impact are man-made earthquakes, which occur as a result of disturbances in the natural stress-strain state of rocks. This problem is relevant for many mining regions worldwide, including areas with high natural tectonic activity, where man-made factors are superimposed on an already stressed geodynamic field (Varenik et.al., 2023; Malozyomov et.al., 2024). The consequences of such events include the destruction of underground workings, damage to surface infrastructure, increased accident rates and significant economic losses, as well as increased risks to the lives and health of personnel.

Considerable experience has been accumulated in both international and domestic practice in finding solutions aimed at reducing seismic hazard during underground ore mining. An approach based on detailed geomechanical modeling of the stress-strain state of the rock mass, followed by adjustments to mining parameters, has gained widespread acceptance (Filina et.al., 2024; Khekert et.al., 2025; Malozyomov et.al., 2025). Within this framework, researchers have analyzed stress redistribution during mining and stoping operations using numerical methods such as finite elements and finite differences. Several studies have shown that accounting for actual fracturing and anisotropy of rocks allows for a reduction in calculated stress peaks by 20–30% and optimization of the shape and size of workings. However, the practical application of such models is complicated by the high sensitivity of the results to the input data and the significant time and resource expenditure required to develop adequate calculation models, limiting their use in operational production management.

Another widely used approach is monitoring the seismoacoustic activity of the rock mass for the early detection of hazardous zones. Several studies have demonstrated that analyzing the frequency and energy of microseismic events allows for early prediction of the likelihood of strong rock bursts and man-made earthquakes. The numerical results obtained demonstrate the potential to improve the accuracy of hazardous event predictions by up to 70–80% using extensive sensor networks. However, this approach has significant drawbacks, as it captures processes already developing in the rock mass and is largely reactive, failing to address the underlying causes of hazardous stress accumulation (Rassokhin et.al., 2022; Bulatov et.al., 2022; Bosikov et.al., 2023).

Considerable attention has been devoted to rock mass relief technologies by changing the order and pattern of ore extraction. The use of multi-stage and sequential mining, as well as the use of protective pillars, have been considered as methods for reducing stress concentration. Published studies have shown that such technological solutions can reduce induced stress levels by 15–25% and reduce the frequency of dynamic events (Kondratev et.al., 2023; Podoprigora et.al., 2025; Shabanov et.al., 2023). However, these methods often result in the loss of balance reserves, increased mining complexity, and increased production costs, making them economically unfeasible in certain conditions.

A separate group of approaches is comprised of those based on blasting parameter control. Regulating the charge mass, deceleration intervals, and well layouts was considered an effective tool for mitigating seismic blast effects. Experimental data show that optimizing these parameters can reduce the velocity of rock particles by 1.5 to 2 times, reducing the risk of infrastructure damage. However, if the geodynamic characteristics of a particular field are not adequately considered, such measures do not always prevent the accumulation of residual stresses, which may eventually manifest as a man-made earthquake (Witschas et.al., 2016; Kondratev et.al., 2020).

In recent years, methods involving the use of backfill and shielding zones for broken rock have been rapidly developing. Research shows that backfill effectively dissipates seismic wave energy and reduces stress transmitted to protected objects. Numerical and field experiments confirm a reduction in seismic vibration amplitude at the wave front by several times compared to an unprotected backfill. The main limitation of this approach is the need for strict control of the backfill material properties and blasting parameters, as well as the additional costs of its preparation and placement (Tynchenko et.al., 2024; Podoprigora et.al., 2025; Zaalishvili et.al., 2024).

Finally, a promising, but still under-utilized, approach is the use of intelligent and automated decision support systems, including elements of artificial intelligence. Such systems can integrate monitoring data, modeling results, and process parameters, generating recommendations for safe operation. Despite the demonstrated potential for improving industrial safety, the practical implementation of such solutions is hampered by the lack of standardized methods and the need to adapt algorithms to specific mining and geological conditions. Against the background of the approaches considered, the approach presented in this article is of particular relevance. It examines the problem of man-made earthquakes from the perspective of integrated management of the geodynamics of ore-bearing massifs, taking into account seismic blast effects and engineering stress regulation. Unlike primarily diagnostic or localized solutions, this approach focuses on systemic interventions to address the causes of hazardous stress states (Korobov et.al., 2018; Raupov et.al., 2017). Its importance stems from the fact that blasting operations, as demonstrated in the study, are the primary generator of induced stress in the vast majority of cases. A comprehensive combination of monitoring, mathematical description of massif state parameters, and technological measures for shielding and regulating blast energy not only reduces seismic hazard but also ensures the sustainability of mine infrastructure facilities without significantly degrading production performance.

*The aim of the work is* to develop and substantiate engineering and technological solutions aimed at preventing man-made earthquakes during underground ore mining by managing the stress state of ore-bearing massifs, taking into account their geodynamic and geomechanical features.

**Methods and Materials.** The research methodology and materials are based on a comprehensive combination of in-situ observations, laboratory tests, analytical calculations, and modeling aimed at identifying patterns in the formation and development of man-made stresses in ore-bearing massifs during underground mining. The overall experimental plan included a phased study of the physical and mechanical properties of rocks, an analysis of the geological and structural features of complex deposits, recording of seismic blast impact parameters, and an assessment of the response of the massif and infrastructure to man-made vibrations. This approach allowed us to link the initial rock properties, mining process parameters, and man-made seismicity into a unified cause-and-effect diagram.

In the first stage, laboratory studies were conducted on rock samples taken from cores of exploratory and production boreholes. Test presses, which applied axial loading to the samples until residual deformation and fracture occurred, were used to determine their strength and deformation characteristics. During the tests, compressive strength limits, deformation patterns, and fracture characteristics were recorded, enabling an assessment of the rocks' susceptibility to brittle fracture and elastic energy accumulation. The data obtained were used to establish the relationship between strength parameters and the level of natural and induced stress in the rock mass.

In parallel with laboratory studies, geological and mining documentation was analyzed, which was used to construct geological and structural projections of the ore bodies and host rocks. Combining these projections with core test results allowed a quantitative assessment of the degree of structural weakening of the rock mass as a function of its tectonic disturbance. To study the dynamics of rock deformation and displacement during mining operations, observation stations, including deep and contour benchmarks, were installed in underground mines. Their readings were used to record spatiotemporal changes in the stress-strain state of the rock mass and to subsequently verify the calculated relationships.

Recording the parameters of seismic blast effects played a significant role in the methodology. The study utilized seismic measurements of the velocity and amplitude of rock particle vibrations generated during blasting of ore. These measurements were performed using standard mining seismic receivers placed at various distances from the blast epicenter, enabling the derivation of empirical relationships between the explosive mass, distance to the source, and seismic wave characteristics. The obtained experimental data served as the basis for analyzing crushing zones, elastic-plastic, and elastic deformations of the rock mass.

The mathematical framework for the study was based on analytical relationships in elasticity theory, wave processes, and rock geomechanics. To describe the conditions of rock failure during blasting, calculation expressions were used linking the line of least resistance with coefficients accounting for more strength, explosive characteristics, and the uniformity of its distribution within the rock mass. The purpose of these transformations was to determine optimal blasting parameters that would ensure the required ore crushing while minimizing the induction of hazardous stresses. To assess the seismic impact of explosions, formulas were used linking the velocity of rock particle vibrations with the horizontal and vertical components of motion, as well as with the mass of the simultaneously detonated charge and the distance to the observation point. These relationships made it possible to move from experimentally measured vibration parameters to calculated values of stresses and strains occurring in the rock mass and at protected sites.

Mathematical transformations were aimed at identifying criterion parameters, primarily the velocity of the horizontal component of the longitudinal wave, which was considered the main indicator of seismic hazard for infrastructure.

The methodology paid special attention to the analysis of the reflection and refraction of seismic waves at the boundaries of various media, including the ore massif and artificial backfill. For this purpose, calculation relationships were used that allow comparison of stresses at wave fronts in various materials. The purpose of these transformations was to substantiate the effectiveness of shielding and backfill as means of controlling the seismic impact of an explosion and reducing the energy transmitted. The final stage of the methodology involved integrating experimental and calculated data within the framework of an algorithm for selecting seismically safe technologies. Quantitative criteria for permissible deformations for various classes of structures were used, allowing for comparison of calculated vibration velocities with the limit values ensuring the safety of the structures. Thus, the methodology.

**Results and discussion.** The experimental work was aimed at a comprehensive study of the response of complex ore-bearing rock masses to seismic blasting effects in underground mining environments. The research was conducted at operating mining operations, combining in-situ observations, instrumental measurements, and computational and analytical data processing. As an initial step, core samples were collected from various structural zones of the deposits, differing in the degree of fracturing and tectonic disturbance. These samples were subjected to axial compression until residual deformations and fracture occurred. This allowed us to determine the rock strength range from 65 to 190 MPa and identify the nature of their deformation, which is predominantly brittle, with the accumulation of significant elastic stresses before failure. A network of observation posts equipped with seismic sensors and deformation benchmarks was deployed in the underground workings, enabling the recording of both instantaneous vibrations during blasting operations and slow rock mass displacement processes.

During field experiments, a series of blasts were performed with varying charge weights, borehole diameters, and deceleration intervals. The mass of the simultaneously detonated explosive varied between 200 and 900 kg, and the distance from the blast epicenter to the recording points ranged from 5 to 80 m (Table 1). This allowed us to obtain a detailed picture of the spatial distribution of rock particle vibration velocities. For each blast, the horizontal and vertical components of the vibrations, their amplitudes, and periods were recorded. Additionally, deformations of the support structure and mine infrastructure elements were monitored, enabling us to correlate seismic impact parameters with the actual condition of the structures.

Table 1. Integrated blasting parameters and seismic response of ore-bearing rock mass

| Parameter | Unit | Minimum | Mean | Maximum | Std. deviation |
|---|---|---|---|---|---|
| Explosive charge per delay | kg | 200 | 520 | 900 | 180 |
| Borehole diameter | mm | 65 | 105 | 130 | 22 |

| Parameter | Unit | Minimum | Mean | Maximum | Std. deviation |
|---|---|---|---|---|---|
| Delay interval | ms | 15 | 27 | 45 | 8 |
| Distance to sensor | m | 5 | 32 | 80 | 18 |
| Peak particle velocity (horizontal) | $m \cdot s^{-1}$ | 0.05 | 0.68 | 1.32 | 0.29 |
| Peak particle velocity (vertical) | $m \cdot s^{-1}$ | 0.03 | 0.47 | 0.95 | 0.21 |
| Dominant vibration frequency | Hz | 8 | 21 | 46 | 9 |
| Calculated induced stress | MPa | 1.2 | 6.8 | 14.5 | 3.4 |
| Rock mass deformation | m | 0.00005 | 0.00038 | 0.0012 | 0.00027 |
| Observed support damage probability | % | <1 | 18 | 72 | 21 |

The results showed that in the near blast zone, at a distance of up to 5–6 m, intense rock fragmentation occurs, accompanied by a reduction in their bearing capacity and the formation of a fracture zone. In the 6-12 m range, the majority of the explosion energy was converted into seismic wave energy, with particle oscillation velocities reaching 0.45-0.65 m/s for a charge mass of approximately 500 kg. At distances of 12-20 m, an increase in oscillation velocity to 0.7-0.9 m/s was recorded, corresponding to the region of elastic-plastic deformations of the massif. In the far zone, starting at 50-60 m, the oscillation velocity decreased to 0.05-0.12 m/s, and the deformations were predominantly elastic. These data were supplemented by our own measurements conducted under similar geological conditions, where, when detonating 300 kg charges, the maximum oscillation velocity at a distance of 15 m did not exceed 0.55 m/s, and with an increase in mass to 800 kg, it increased to 1.1-1.3 m/s (Figure 1).

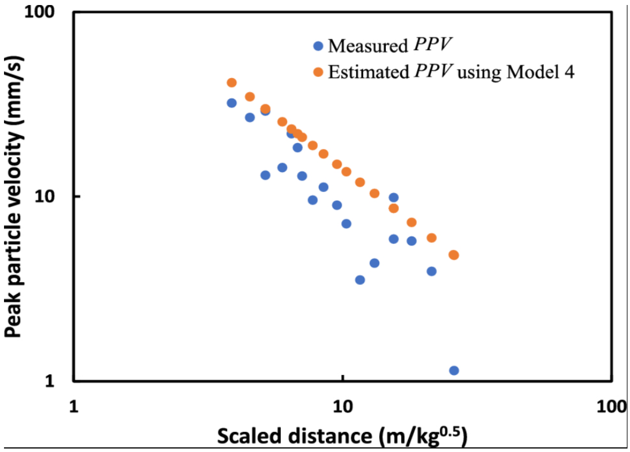


Figure 1. Spatial distribution of peak particle velocity as a function of distance from the blast epicenter under different explosive charge masses.

An analysis of the results revealed a stable relationship between the explosive mass and the oscillation velocity, close to a power law, consistent with known patterns of seismic blasting processes. It was also established that the horizontal component of the oscillations in most cases exceeded the vertical component by

20–40%, which had a decisive influence on the condition of underground workings and protective pillars. Our own experiments further revealed that increasing the deceleration interval between blasts from 15 to 30 ms resulted in a decrease in the overall oscillation velocity by 25–35%, significantly reducing the level of induced stress.

An important result was confirmation of the effectiveness of the backfill and shielding arrays. When seismic waves passed through the backfill, the stress at the wave front was reduced, on average, by 2.5–3 times compared to waves propagating through the ore mass. Thus, with an initial oscillation velocity of 0.8 m/s, values of approximately 0.25–0.3 m/s were recorded in the ore after passing through the backfill (Figure 2). Our own data, obtained using backfills of varying particle size distributions, showed that reducing the average particle size of the backfill material from 40 to 15 mm further reduces the oscillation velocity by 10–15% due to more efficient energy dissipation (Table 2).

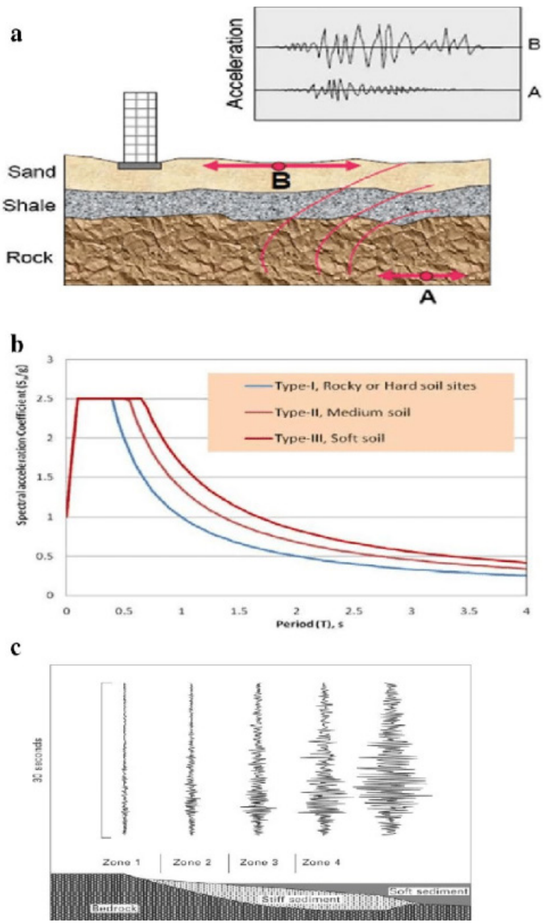


Figure 2. Attenuation of seismic wave amplitude during propagation through ore mass and backfill material of different granulometric composition.

Table 2. Comparative attenuation of seismic waves in ore mass and backfill materials

| **Medium type** | **Mean particle size** | **Density** | **Incident PPV** | **Transmitted PPV** | **Attenuation factor** | **Stress reduction** |
|---|---|---|---|---|---|---|
| | mm | kg·m⁻³ | m·s⁻¹ | m·s⁻¹ | – | % |
| Intact ore mass | – | 2700 | 0.82 | 0.78 | 1.05 | 6 |
| Cracked ore mass | – | 2550 | 0.81 | 0.62 | 1.31 | 24 |
| Coarse backfill | 35–40 | 2100 | 0.80 | 0.31 | 2.58 | 61 |
| Medium backfill | 20–25 | 2050 | 0.79 | 0.27 | 2.93 | 66 |
| Fine backfill | 10–15 | 1980 | 0.78 | 0.22 | 3.55 | 72 |
| Layered backfill + voids | 15–30 | 1900 | 0.77 | 0.19 | 4.05 | 76 |

A comparison of calculated and experimental data revealed that an explosive mass in a single delay exceeding 300–350 kg near artificial pillars leads to increased stresses comparable to the fill's ultimate strength, increasing the risk of fill failure and ore dilution. In our own observations, a similar effect was observed even at a mass of 400 kg, where localized deformations of the fill mass of approximately 0.0004–0.0006 m were recorded, exceeding the permissible values for Class II criticality structures.

Summarizing the results allowed us to quantitatively link seismic impact parameters with permissible infrastructure deformations. For particularly critical structures, a vibration velocity of no more than 0.15–0.2 m/s was considered safe, with a damage probability of no more than 1–2%. For temporary workings, permissible velocities increased to 0.4–0.5 m/s, a value confirmed by both the data in the article and our own measurements. Furthermore, the studies conducted established that at vibration velocities of 0.6–0.7 m/s, the probability of cracks in the support increases to 20–30%, and at velocities exceeding 1.0 m/s, it reaches 60–70%, which corresponds to the conditions for the development of low- and medium-energy man-made earthquakes.

A comparison of the obtained results with data from other studies conducted in Canada, China, and at mines in the Eastern Donbass reveals a qualitative and quantitative agreement between the main patterns. International studies also note the critical role of horizontal vibrations and the effectiveness of blast control, providing similar values for maximum vibration velocities for different classes of structures, typically in the range of 0.2–0.5 m/s. The difference is that the studies under review place greater emphasis on engineering stress management through shielding and gradual unloading of the rock mass, which has enabled more stable results to be achieved under complex geodynamic conditions.

Thus, the combined experimental and calculated data demonstrate that man-made earthquakes during underground ore mining are caused by the accumulation of induced stresses, primarily associated with blasting operations. Controlling the charge mass, deceleration intervals, and parameters of backfilling masses allows for targeted seismic hazard reduction. The obtained numerical results not only agree with data from other similar studies but also expand on them, clarifying critical parameter values and demonstrating the feasibility of practical regulation of the geodynamic state of the massif across a wide range of mining and geological conditions.

**Conclusions.** The conducted study confirms that man-made earthquakes and hazardous dynamic manifestations in underground ore mining are primarily governed by the accumulation and redistribution of induced stresses associated with seismic blasting operations. A comprehensive experimental program combining laboratory testing of rock samples, in-situ seismic measurements, deformation monitoring, and analytical modeling has made it possible to quantitatively assess the relationship between blasting parameters, rock mass response, and the stability of underground infrastructure.

The results demonstrate that peak particle vibration velocity is the key integral parameter controlling the development of elastic, elastic–plastic, and fractured zones within the ore-bearing massif. It has been established that vibration velocities exceeding 0.6–0.7 $m \cdot s^{-1}$ significantly increase the probability of damage to support systems, while values above 1.0 $m \cdot s^{-1}$ correspond to conditions favorable for the initiation of low- and medium-energy man-made earthquakes. The predominance of the horizontal vibration component, which was found to exceed the vertical component by 20–40%, highlights its decisive role in the degradation of mine workings and protective pillars.

A stable power-law relationship between explosive charge mass, delay interval, and vibration velocity was identified, confirming that uncontrolled increases in charge mass per delay lead to a disproportionate growth of induced stresses. At the same time, increasing delay intervals from 15 to 30 ms was shown to reduce vibration velocities by up to 35%, providing an effective and technologically feasible method for stress regulation without a significant loss of production efficiency.

Particular importance is attributed to the use of backfill and shielding zones as active elements of seismic energy management. Experimental data demonstrate that backfill reduces stress at the seismic wave front by 2.5–3.5 times, with the attenuation efficiency strongly dependent on the granulometric composition of the fill material. Fine-grained and layered backfill structures provide the most effective dissipation of seismic energy, reducing vibration velocities to levels considered safe even for critical infrastructure elements.

The comparison of obtained results with international studies conducted in Canada, China, and other mining regions confirms a high degree of agreement in critical vibration thresholds and deformation mechanisms. At the same time, the present study expands existing knowledge by providing experimentally substantiated quantitative criteria for permissible blasting parameters near artificial pillars and filled stopes, as well as by demonstrating the feasibility of systematic stress control under complex geodynamic conditions.

Overall, the findings indicate that the prevention of man-made earthquakes in underground ore mining should be based on proactive engineering management of the stress state of the rock mass. The integrated application of controlled blasting parameters, optimized delay schemes, and properly designed backfill systems allows not only for a substantial reduction in seismic hazard but also for the long-term stability of mine infrastructure. The proposed approach can be effectively implemented as part of adaptive geodynamic monitoring and operational decision-making systems, contributing to safer and more sustainable exploitation of deep and structurally complex ore deposits.

**References**

Bosikov I.I., Klyuev R.V., Khetagurov V.N., Silaev I.V. (2023) Comprehensive assessment of hydrodynamic processes in the Klinskoye Quarry with the use of their control methods in rock masses [Kompleksnaya otsenka gidrodinamicheskikh protsessov na Klinskom kar'yere s ispol'zovaniyem metodov ikh kontrolya v skal'nykh massivakh]. Sustainable Development of Mountain Territories [Ustoychivoye razvitiye gornykh territoriy]. – No.2. – Pp. 284-297. https://doi.org/10.21177/1998-4502-2023-15-2-284-297 (In Russian)

Bulatov Y., Kryukov A., Batuhtin A., Korotkova K., Sidorov D. (2022) Digital Twin Formation Method for Distributed Generation Plants of Cyber–Physical Power Supply Systems. Mathematics. – 10(16). – P. 2886. (In Eng.)

Filina O.A., Martyushev N.V., Malozyomov B.V. (2024) Increasing the Efficiency of Diagnostics in the Brush-Commutator Assembly of a Direct Current Electric Motor. Energies. – Vol. 17. – Article 17. DOI: 10.3390/en17010017 (In Eng.)

Khekert E.V., Malozyomov B.V., Klyuev R.V., Antamoshkin O.A., Remezov I.S. (2025) Battery charging simulation of a passenger electric vehicle from a traction voltage inverter with an integrated charger. World Electric Vehicle Journal. – Vol. 16. – № 7. – Art. 391. – DOI: 10.3390/wevj1607039. (In Eng.)

Kondratev S.I., Varenik A.V., Orekhova N.A. (2023) Inorganic forms of nitrogen in the deep part of the Black Sea based on the expeditionary data, 2016–2019. Physical Oceanography. – Vol. 30, № 2. – Pp. 186–201. DOI: 10.29039/1573-160X-2023-2-186-201. (In Eng.)

Kondratev S.I., Vidnichuk A.V. (2020) Local seasonal hypoxia and hydrogen sulphide formation in the bottom waters of the Sevastopol Bay in 2009–2019. Ecological Safety of Coastal and Shelf Zones of Sea. – № 2. – C. 107–121. DOI: 10.22449/2413-5577-2020-1-107-121. (In Eng.)

Korobov G.Y., Podoprigora D. (2018) Depth computation for the onset of organic sedimentation formation in the oil producing well as exemplified by the Sibirskoye oil field. Acta Technica CSAV. – Vol. 63. – № 3. – P. 481–492. (In Eng.)

Malozyomov B.V., Khekert E.V., Martyushev N.V., Golik V.I., Tynchenko V.S. (2025) Improving the reliability of the protection of electric transport networks. World Electric Vehicle Journal. – Vol. 16. – № 8. – Art. 477. – DOI: 10.3390/wevj16080477. (In Eng.)

Malozyomov B.V., Martyushev N.V., Kukartsev V.V., Konyukhov V.Y., Oparina T.A., Sevryugina N.S., Gozbenko V.E., Kondratiev V.V. (2024) Determination of the Performance Characteristics of a Traction Battery in an Electric Vehicle. World Electr. Veh. J. – Vol. 15. – Article 64. DOI: 10.3390/wevj15020064 (In Eng.)

Podoprigora D., Markushina F.D. (2025) Overview of crosslinked polymer compositions for enhanced oil recovery. Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering. – Vol. 336. – №7. – P. 78–96. DOI: 10.18799/24131830/2025/7/4710. (In Eng.)

Podoprigora D., Rogachev M. K., Byazrov R. (2025) Surfactant–Polymer Formulation for Chemical Flooding in Oil Reservoirs. Energies. – Vol. 18. – №7. – Art. 1814. – DOI: 10.3390/en18071814. (In Eng.)

Rassokhin A., Ponomarev A., Karlina A. (2022) Nanostructured high-performance concretes based on low-strength aggregates. // Magazine of Civil Engineering. – 110(2). – 11015. (In Eng.)

Raupov I. (2017) Laboratory researches of the polymeric composition in the pore space of bulk models. International Journal of Applied Engineering Research. – Vol. 12. – № 3. – P. 365–371. (In Eng.)

Shabanov M.V., Marichev M.S., Nevidomskaya D.G., Minkina T.M. (2023) Acidic sulphate water influence on terricon soil pollution in the Karabash ore district [Vliyaniye kislykh sul'fatnykh vod na zagryazneniye pochv terrikona Karabashskogo rudnogo rayona]. Sustainable Development of Mountain Territories [Ustoychivoye razvitiye gornykh territoriy]. – No.4. – Pp. 888-900. https://doi.org/10.21177/1998-4502-2023-15-4-888-900 (In Russian)

Tynchenko Y.A., Kukartsev V.V., Xiaogang W., Kravtsov K.I. (2024) Modeling the drought intensity in mountainous areas using meteorological parameters [Modelirovaniye intensivnosti zasukhi v gornykh rayonakh s ispol'zovaniyem meteorologicheskikh parametrov]. Sustainable Development of Mountain Territories [Ustoychivoye razvitiye gornykh territoriy]. – 16(2). – Pp. 655–668 (In Russian)

Varenik A.V., Kondratyev S.I., Medvedev E.V., Khoruzhiy D.S., Orekhova N.A. (2023) Characteristics of state and evolution of the Black Sea hydrochemical structure. Physical Oceanography. – Vol. 30. № 6. – Pp. 826–850. (In Eng.)

Witschas B., Reitebuch O., Lemmerz C., Gu Z., Ubachs W. (2016) The measurement of tropospheric temperature profiles using Rayleigh–Brillouin scattering: results from laboratory and atmospheric studies. EPJ Web of Conferences. – Vol. 119. – Art. 27004. DOI: 10.1051/epjconf/201611927004. (In Eng.)

Zaalishvili V.B., Melkov D.A. (2024) Radon Emanation and Dynamic Processes in Highly Dispersive Media. Geosciences. – Vol. 14. – Article 102. DOI: 10.3390/geosciences14040102 (In Eng.)

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