# GEOTECHNICAL BASIS OF CONTOUR BLASTING AND ITS INFLUENCE ON UNDERGROUND EXCAVATION STABILITY IN COMPLEX GEOLOGICAL CONDITIONS

**Solikhov Javlonbek Tohkhir o‘g‘li**
*Assistant, Department of Mining Engineering, TashSTU*
**Maxmudov Dilmurod Raxmatjonovich**
*Associate Professor, Department of Mining Engineering, TashSTU*
**Ualiev Makhmud Kidirbayevich**
*Assistant, Department of Mining and Metallurgy, NSTU*
**Joldasbaev Atabek Maylibaevich**
*Assistant, Department of Mining and Metallurgy, NSTU*
**Orazbaev Aymurza Jetpisbay ulu**
*Master’s student, Department of Mining and Metallurgy, NSTU*

**Abstract.** This paper presents a comprehensive investigation of the geotechnical basis of contour blasting and its influence on the stability of underground excavations in complex geological conditions. The relevance of the study is driven by the increasing need to ensure excavation stability in rock masses characterized by tectonic disturbances, intensive jointing, and structural heterogeneity. The research analyzes stress redistribution mechanisms induced by blasting, the formation of blast-damaged zones in the near-contour region, and the interaction between blasting parameters and geomechanical factors. The results demonstrate that geotechnically justified contour blasting significantly reduces overbreak, improves excavation profile accuracy, and preserves the mechanical integrity of the surrounding rock mass. The findings provide a scientific foundation for optimizing contour blasting design and enhancing the safety and efficiency of underground excavation in complex geological environments.

**Keywords:** contour blasting; underground excavations; complex geological conditions; geotechnical basis; rock mass behavior; excavation stability; blast-damaged zone; overbreak control; stress redistribution.

**Аннотация.** В статье выполнено комплексное исследование геотехнических основ контурного взрывания и его влияния на устойчивость подземных выработок в сложных геологических условиях. Актуальность работы обусловлена необходимостью повышения устойчивости контуров выработок в массивах горных пород, характеризующихся тектоническими нарушениями, высокой трещиноватостью и неоднородностью строения. Рассмотрены процессы перераспределения напряжений при взрывном воздействии, механизмы формирования зон разрушения в приконтурной области и влияние технологических параметров буровзрывных работ на



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геомеханическое состояние массива. Показано, что геотехнически обоснованный выбор параметров контурного взрывания позволяет существенно снизить избыточные разрушения, повысить точность формирования профиля выработки и обеспечить её долговременную устойчивость. Полученные результаты могут быть использованы при проектировании и ведении подземных горных работ в сложных кон-геологических условиях.

**Ключевые слова:** контурное взрывание; подземные выработки; сложные геологические условия; геотехнические основы; массив горных пород; устойчивость выработок; зона взрывного повреждения; избыточное разрушение массива; перераспределение напряжений.

**Annotatsiya.** Mazkur maqolada murakkab kon-geologik sharoitlarda yer osti lahimlarini o‘tishda konturli portlatish texnologiyasining geotexnik asoslari hamda uning lahimlar barqarorligiga ta’siri kompleks ravishda tadqiq etilgan. Tadqiqotning dolzarbligi tog‘ jinslari massivining notekis tuzilishi, yuqori darajadagi yoriqlanish va tektonik buzilishlar mavjud bo‘lgan sharoitlarda portlatish ishlari natijasida yuzaga keladigan ortiqcha buzilishlar va barqarorlik muammolari bilan belgilanadi. Ishda portlatish jarayonida kuchlanishlarning qayta taqsimlanishi, kontur yaqinidagi buzilish zonalarining shakllanish mexanizmlari hamda burg‘ilab-portlatish parametrlarining geomekanik omillar bilan o‘zaro bog‘liqligi tahlil qilingan. Geotexnik jihatdan asoslangan konturli portlatish parametrlarini qo‘llash ortiqcha buzilishlarni kamaytirish, lahim kesimi aniqligini oshirish va tog‘ jinslari massivining uzoq muddatli turg‘unligini ta’minlash imkonini berishi ko‘rsatib berilgan. Olingan natijalar murakkab kon-geologik sharoitlarda yer osti qazib olish va tunnellarni qurishda portlatish texnologiyalarini takomillashtirish uchun ilmiy-amaliy ahamiyatga ega.

**Kalit so‘zlar:** konturli portlatish; yer osti lahimlari; murakkab geologik sharoitlar; geotexnik asoslar; tog‘ jinslari massivi; lahim barqarorligi; portlatishdan keyingi buzilish zonasi; ortiqcha buzilish (overbreak); kuchlanishlarning qayta taqsimlanishi.

## INTRODUCTION

The progressive deepening of underground mining and tunneling has intensified geological and geotechnical challenges associated with excavation stability. In many mining regions, underground openings are developed within complex geological environments characterized by tectonic disturbances, heterogeneous lithology, anisotropic rock mass structures, and highly variable in situ stress conditions. These factors significantly influence the response of the rock



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mass to excavation and often lead to excessive overbreak, degradation of the excavation contour, and increased requirements for ground support.

Drilling and blasting remains the dominant excavation method in hard rock underground construction due to its operational flexibility and economic feasibility. However, conventional blasting approaches frequently generate uncontrolled damage in the near-contour zone, where stress redistribution and blast-induced tensile fracturing compromise the mechanical integrity of the surrounding rock mass. Such damage not only reduces the stability of underground openings but also accelerates long-term deformation processes and increases maintenance costs.

Contour blasting has been developed as a controlled blasting technique aimed at minimizing blast-induced damage while preserving the designed excavation profile. The effectiveness of this method is strongly dependent on the geotechnical justification of technological parameters, including borehole spacing, charge concentration, decoupling ratio, and initiation sequence. In complex geological conditions, empirical parameter selection is often insufficient, as the interaction between blasting-induced stress waves and pre-existing discontinuities can significantly alter fracture development.

Despite numerous studies addressing blasting optimization, the geotechnical mechanisms governing contour stability under complex geological conditions remain insufficiently systematized. In particular, the influence of tectonic structures and heterogeneous stress redistribution on contour blasting performance requires further investigation.

This study aims to establish a geotechnically grounded framework for contour blasting design and to assess its influence on underground excavation stability in complex geological environments. The findings contribute to improving excavation quality, enhancing operational safety, and reducing the economic impact of blast-induced damage in underground mining and tunneling projects.

**Table-1.**

**Geological and Geotechnical Factors Influencing Underground Excavation Stability**

| Factor | Description | Influence on Excavation Stability |
|---|---|---|
| **Lithology** | Mineral composition and texture of rock | Controls strength, brittleness, and fracture behavior |



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| | | |
|---|---|---|
| **Jointing and fractures** | Density, orientation, persistence of discontinuities | Reduces rock mass strength and promotes block instability |
| **Faults and shear zones** | Zones of crushed and altered rock | Increase deformation and overbreak risk |
| **Rock mass anisotropy** | Direction-dependent mechanical properties | Causes uneven stress redistribution |
| **In situ stress magnitude** | Vertical and horizontal stress levels | Governs spalling, slabbing, and stress-induced failure |
| **Stress orientation** | Direction of principal stresses | Affects excavation shape stability |
| **Groundwater conditions** | Presence of water in joints and pores | Reduces effective strength and promotes loosening |
| **Rock mass quality (RMR, GSI)** | Integrated classification indices | Determines excavation support and blasting strategy |

Geological and geotechnical conditions affecting excavation stability. The stability of underground excavations is fundamentally controlled by geological and geotechnical conditions of the rock mass. In complex geological environments, excavation behavior is influenced not only by intact rock properties but also by structural features such as faults, joints, folds, and lithological contacts. These factors govern stress redistribution, deformation mechanisms, and the extent of blast-induced damage around underground openings. One of the most critical geological factors affecting excavation stability is the presence of tectonic disturbances. Fault zones and shear zones significantly reduce rock mass strength due to intense fracturing and alteration. Excavations intersecting such zones are prone to excessive deformation, overbreak, and progressive instability, especially when blasting-induced tensile stresses activate pre-existing discontinuities. Rock mass heterogeneity and anisotropy further complicate excavation stability. Variations in lithology, bedding orientation, and joint persistence lead to non-uniform stress redistribution around underground openings. As a result, localized zones of stress concentration and tensile failure may develop even under predominantly compressive in situ stress conditions.

From a geotechnical perspective, in situ stress magnitude and orientation play a decisive role in excavation response. With increasing depth, higher stress levels intensify excavation-induced stress redistribution, which may trigger spalling, slabbing, or strain bursting in strong brittle rocks. In weaker or heavily jointed rock masses, stress relaxation near excavation boundaries often results in dilation and loosening of the rock mass. The interaction between geological



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structures and blasting processes is particularly important for contour stability. Improperly designed blasting parameters may amplify damage along discontinuities, enlarging the blast-damaged zone and reducing the load-bearing capacity of the near-contour rock mass. Therefore, a comprehensive assessment of geological and geotechnical conditions is essential for designing effective contour blasting schemes.

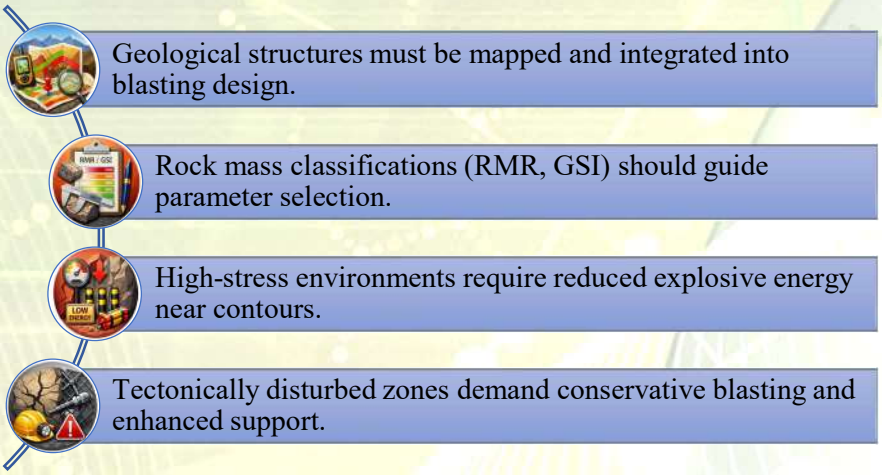



**Fig-1. Key implications for contour blasting design**

Geotechnical principles of contour blasting. Contour blasting is a controlled drilling and blasting technique aimed at minimizing blast-induced damage while preserving the integrity and stability of underground excavation boundaries. Its geotechnical foundation is based on the interaction between explosive energy, rock mass properties, in situ stress conditions, and excavation geometry. In complex geological environments, improper contour blasting can result in excessive overbreak, development of tensile cracks, loosening of the near-contour rock mass, and a significant reduction in long-term excavation stability. One of the primary geotechnical principles of contour blasting is energy regulation near the excavation perimeter. Reduced charge concentration, decoupled explosives, and increased borehole spacing along the contour are applied to limit the peak particle velocity (PPV) and tensile stress development in the surrounding rock. This is particularly critical in fractured, tectonically disturbed, or high-stress rock masses, where stress redistribution after blasting may trigger secondary failure mechanisms.

Another key principle is the orientation of contour boreholes relative to geological discontinuities. Joints, faults, foliation planes, and bedding surfaces significantly influence crack propagation paths. When boreholes are aligned parallel to dominant discontinuity sets, blast-induced fractures tend to propagate preferentially along existing weakness planes, increasing overbreak. Therefore, geological structure mapping and geotechnical characterization must be integrated into contour drilling design. Rock mass quality indicators such as RMR (Rock Mass Rating) and GSI (Geological Strength Index) play a decisive role in selecting


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contour blasting parameters. Lower-quality rock masses require conservative designs with lower specific charge, shorter advance lengths, and enhanced support installation immediately after blasting. Conversely, massive and competent rock masses allow for moderately higher energy input without compromising excavation stability. In deep underground excavations, in situ stress conditions strongly affect contour blasting efficiency. High horizontal or anisotropic stresses may lead to stress-induced spalling and slabbing even with controlled blasting. In such environments, contour blasting must be combined with stress relief techniques, optimized delay timing, and appropriate excavation sequencing to prevent instability.

**Table-1.**

**Geotechnical principles governing contour blasting design in underground excavations**

| Geotechnical factor | Influence on contour blasting | Design implication |
|---|---|---|
| **Rock mass quality (RMR, GSI)** | Controls fracture development and damage zone thickness | Lower RMR/GSI → reduced charge, increased spacing |
| **Geological discontinuities (faults, joints)** | Guide crack propagation and overbreak formation | Borehole orientation adjusted to discontinuity sets |
| **In situ stress magnitude** | Affects tensile crack initiation and spalling | Reduced explosive energy near contours |
| **Stress anisotropy** | Causes asymmetric damage around excavation | Directional blasting and staged excavation |
| **Rock tensile strength** | Determines resistance to blast-induced cracking | Selection of decoupling ratio and charge type |
| **Excavation geometry** | Influences stress redistribution | Smooth blasting and precise contour definition |

Influence of contour blasting on excavation stability. Geotechnically optimized contour blasting directly contributes to excavation stability by preserving the mechanical integrity of the surrounding rock mass. Reduced blast-induced damage leads to:

- Lower stress redistribution gradients,
- Improved load-bearing capacity of the near-contour zone,
- Reduced demand for heavy ground support systems,
- Enhanced long-term stability of underground openings.



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Field observations and numerical modeling studies confirm that properly designed contour blasting significantly decreases overbreak and improves contour smoothness, especially in tectonically disturbed rock masses. The results of this study emphasize that contour blasting should not be treated as a purely technological process but as a geotechnically controlled excavation method. The interaction between blasting parameters and geological conditions plays a decisive role in excavation performance. In complex geological environments, the integration of geological mapping, rock mass classification, stress analysis, and numerical modeling is essential for reliable blasting design. Failure to consider these factors may lead to excessive damage, instability, and increased operational costs. The analysis demonstrates that tectonic disturbances, jointing intensity, and anisotropy of the rock mass significantly influence blast-induced crack propagation and the formation of the excavation damaged zone. In such environments, uncontrolled explosive energy near excavation boundaries leads to excessive overbreak, tensile fracturing, and progressive degradation of rock mass strength. The application of reduced charge concentration, decoupled explosives, optimized borehole spacing, and controlled initiation sequences is therefore essential for minimizing damage to the near-contour zone. It is established that rock mass classification systems such as RMR and GSI provide a reliable geotechnical basis for selecting contour blasting parameters.

Lower-quality and tectonically disturbed rock masses require conservative blasting designs combined with immediate installation of support systems, while competent rock masses allow for more flexible parameter selection without compromising excavation stability. The results also highlight the dominant role of in situ stress conditions in deep underground excavations. High stress levels and stress anisotropy amplify the negative effects of blasting, making it necessary to reduce explosive energy near contours and coordinate blasting design with excavation sequencing and support strategies.

## REFERENCES

1. Hoek, E., & Brown, E. T. (2019). The Hoek–Brown failure criterion and GSI – 2018 edition. Journal of Rock Mechanics and Geotechnical Engineering, 11(3), 445–463.
2. Konya, C. J., & Walter, E. J. (1990). Rock blasting and overbreak control. U.S. Department of the Interior, Bureau of Mines.
3. Olofsson, S. O. (1990). Applied explosives technology for construction and mining. Applex, Sweden.
4. Persson, P. A., Holmberg, R., & Lee, J. (1994). Rock blasting and explosives engineering. CRC Press, Boca Raton.



ISSN 3030-3907

5. Brady, B. H. G., & Brown, E. T. (2006). Rock mechanics for underground mining (3rd ed.). Springer, Dordrecht.



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