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Stress state of rock mass during stoping under pit bottom in the presence of slide rocks on the pit bottom

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Abstract. The article studies influence of slide rocks on the bottom of Internationalny open pit mine on stress state of rock mass during stoping under the pit bottom. The stress distribution during extraction of ore reserves from the initial layer under the pit bottom is determined. The post-limiting deformation zones in ore body during formation of a crown pillar are delineated using the Mohr–Coulomb criterion. The authors give a predictive estimate of alteration in stress state of the crown pillar with the advance of stoping.

1. Introduction

Internationalnaya kimberlite pipe represented by the subvertical oval ore body with the transverse cross-section 60×104 m is developed by ALROSA the top-down cut-and-fill method with layers 4–5 high and stopes 5–6 m wide. For safe extraction of ore reserves under the open pit mine bottom in complex hydro-geomechanical conditions, it is planned to arrange a protective crown pillar 35 m thick.

Safe mining of kimberlite resources calls for persistent improvement of standards and procedures based on integrated researches [1]. The most effective approach to the assessment of crown behavior, alongside with rock mechanics [2–5], instrumental and visual techniques, are the mathematical modeling methods which allow description of features and regular patterns of stress state in the crown in case of the alteration of geotechnical situation in rock mass under the pit bottom and hydrological situation within the open pit void [6, 7].

This study aims to analyze and predict geomechanical situation under the open pit mine bottom in such cases as wet slide rocks on the pit bottom and advance of stoping under the bottom.

2. Stress state estimation

Stress state under the open pit bottom was estimated based on numerical calculation data obtained using the method of boundary integral equations and elastic model adapted to the open pit mine conditions [6–8]. The problems were solved for the real geometry of the open pit. The depth of Internationalny mine is 315 m (bottom level is +85 m). Currently, it is filled with slide rocks up to the level of +120 m. Water level in the pit is +115 m.

The natural field of stresses for the mine is assumed as $\sigma_y^0 = -\gamma H$, $\sigma_x^0 = -\lambda\gamma H$, where σ_x^0 , σ_y^0 are the horizontal and vertical stresses; $\lambda = 1$ is the lateral earth pressure coefficient [9]; γ is the bulk density of rocks, MN/m³; H is the mining depth, m. The calculations included the average modulus of deformation $E = 7.5$ GPa and Poisson's ratio $\nu = 0.25$ [10–12]. The interpretation of the calculated



results used such values of stresses σ_s which permitted employment of the Mohr–Coulomb criterion [5, 8]:

$$\sigma_s = \frac{\sigma_1 - \sigma_3}{2 \cos \varphi} + \frac{\sigma_1 + \sigma_3}{2} \tan \varphi,$$

where $\sigma_1 > \sigma_2 > \sigma_3$ are the principal stresses; φ is the internal friction angle.

From the visual observations and numerical calculations for a pilot extraction block (PEB 2), it has been found that failure of rock mass in the open pit bottom takes place in the zones where $\sigma_s > 4$ MPa [6–8]. Thus, $\sigma_s^k = 4$ MP is assumed as the critical value.

After completion of open pit mining, zones of higher horizontal stresses and vertical stress relaxation appear in the pit bottom rocks. It is planned to form a crown pillar by cutting and filling in the initial layer at a distance of 35 m from the pit bottom (Figure 1). After extraction of the first-phase stopes in the initial cut layer, the compressive stresses σ_x at the top of the crown grow up to $-16 \div -18$ MPa (Figure 1a).

Relaxation of vertical stresses is observed under the pit bottom and in the roof of the first-phase stopes (Figure 1b). In the pillars between these stopes, σ_y reaches -12 MPa. Completion of mining in the initial layer results in the increase in σ_x to $-20 \div -22$ MPa (Figure 1c) and total relaxation of σ_y along the height of the crown (Figure 1d).

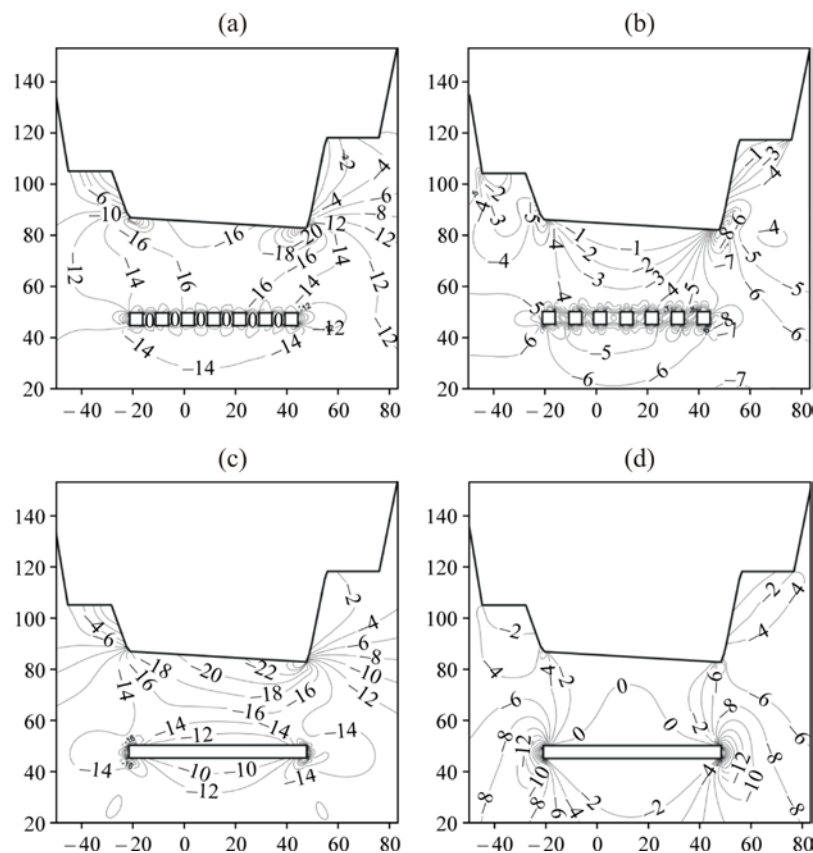


Figure 1. Horizontal stress σ_x and vertical stress σ_y (MPa) in rock mass under the open pit bottom after (a), (b) extraction of the first-phase stopes in the initial layer and (c), (d) upon completion of mining in the layer.

Thus, the horizontal stresses σ_x in the crown are the determinant, and the further analysis of the stress state uses the calculated data on σ_x .

When the open pit is filled with slid rocks up to the level of +120 m (Figure 2) and when the fill gets wet to the level of 115 m, additional load on the crown is [5]:

$$P_z = \zeta \gamma_1 H_1 + (1 - \zeta) \gamma_2 H_2,$$

where $\zeta = 0.7$ is the degree of fragmentation in slide rocks; $\gamma_1 = 0.022$ is the bulk density of rocks, MN/m³; $\gamma_2 = 0.01$ is the bulk density of water, MN/m³; H_1 is the thickness of slide rocks; H_2 is the thickness of wet rocks.

Additional load on the crown induces an increase in the compressive stresses σ_x under the pit bottom, especially in the concentration zones during the first-phase stoping (Figure 2a), and in σ_x by $\approx 10\%$ after completion of stoping in the first layer. In the meanwhile, stress distribution in the roof of the initial cut-and-fill layer is insignificant (Figures 1c and 2b).

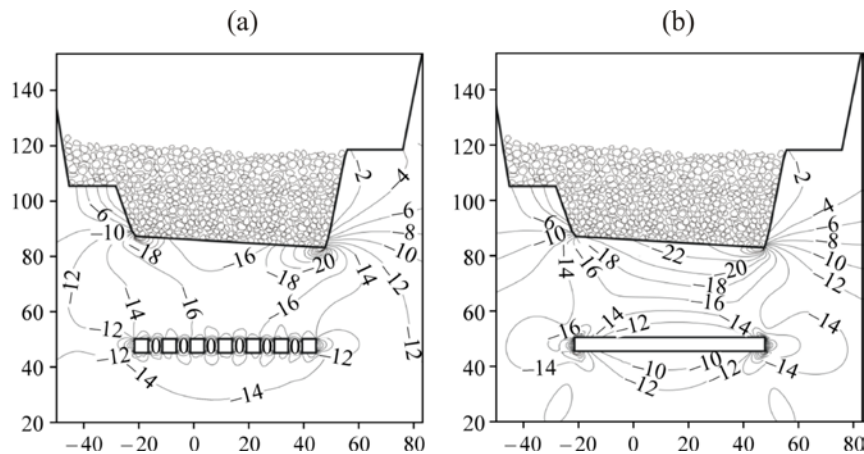


Figure 2. Horizontal stress σ_x (MPa) under the pit bottom with regard to additional load after extraction of (a) the first-phase stopes and (b) the whole layer.

As stoping is advanced, the compressive stresses σ_x in the crown essentially grow across its thickness: to 28 MPa under the pit bottom without slide rocks (Figure 3a), as well as to 26 MPa in the stopping roof and to 30–32 MPa under the pit bottom in case of slide rocks.

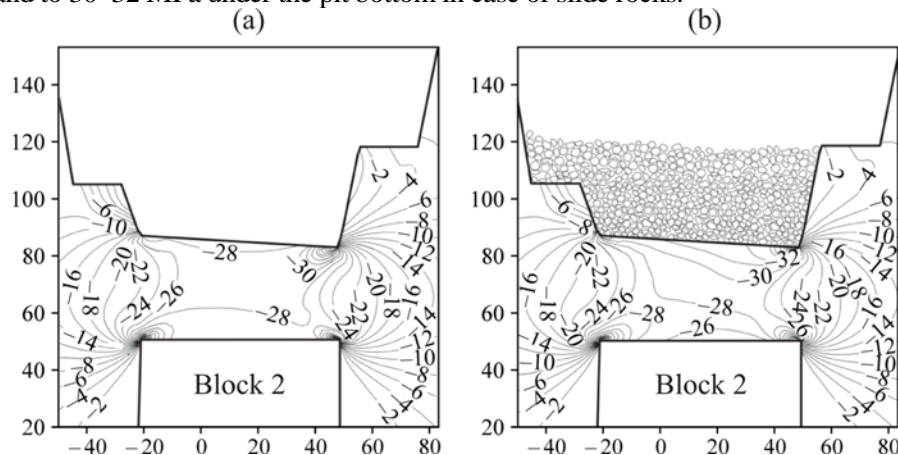


Figure 3. Horizontal stress σ_x (MPa) under the pit bottom (a) without and (b) with additional load on the crown after completion of stoping in the pilot block.

3. Inelastic strain zones behavior

Behavior of inelastic strain zones with taking into account additional load in the open pit allows drawing some conclusions (Figure 4). During the first-phase stoping in the initial layer, the inelastic strain zones are formed under the pit bottom, at the corner areas of the pit bottom and pit walls, as well as near the stopes at the ends of the layer (Figure 4a). Complete extraction of ore reserves from the initial layer changes essentially the deformation pattern in the crown and nearby it: the inelastic strains embrace considerable portion of the crown; in the roof of the layer at the interface of enclosing rock mass and kimberlites, the inelastic strain zones expand to 2–2.5 m depthward (Figure 4b).

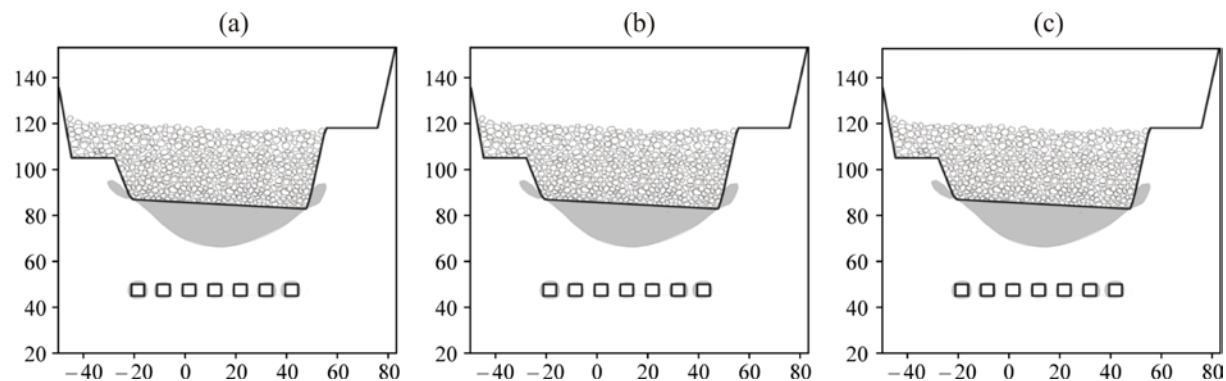


Figure 4. Formation of inelastic strain zones during stoping advance in the initial layer under open pit mine bottom: (a) the first-phases stopes are extracted; (b) initial layer stoping is completed; (c) mining in block 2 is completed.

After total extraction of block 2, the inelastic strain zones spreads across and along the thickness of the crown. The inelastic strain zones develop at a distance of 200 m from the pit bottom and inward enclosing rock mass (Figure 4c).

In this manner, the pre-estimate of stresses and strains induced in rock mass under the open pit bottom by slide rocks on the bottom and by stoping proves the essential increase in the horizontal stresses which cause inelastic strains in the ore crown pillar and in enclosing rock mass at the open pit bottom. In particular, at the present boundary conditions in the accepted geomechanical model, the post-limiting deformation domains at the final stage of stoping in block 2 encompass a greater portion of the crown and the lower part of rock mass at the pit bottom and pit walls up to the level of 105–110 m.

Acknowledgements

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References

- [1] Trubetskoy KN, Kaplunov DR and Rylnikova MV 2011 Problems and prospects of geotechnological innovation in the sphere of integrated kimberlite resources management *Problems and Ways of Efficient Diamond Mining: International Conference Proceedings* Novosibirsk: Nauka (in Russian)
- [2] Mathews KN, Hoek E, Wyllie DC and Stewart SBV 1980 Prediction of stable excavation spans for mining at depths below 1,000 meters in hard rock *Golder Associates Report to Canada Centre for Mining and Energy Technology (CAANMET)*, Department of Energy and Resources Ottawa Canada
- [3] Laubscher DN 1990 A geomechanics classification system for the rating of rock mass in mini design *J. S. Afr. Min. Metall.* No 10 pp 257–273
- [4] Barton N 1993 Application of Q-system and index tests to estimate shear strength and deformability of rock masses *Workshop on Norwegian Method of Tunneling* New Delhi pp 66–84

- [5] Bulychiev NS 1989 *Mechanics of Underground Structures* Moscow: Nedra (in Russian)
- [6] Baryshnikov VD and Gakhova LN 2017 Stress-strain state of adjacent rock mass under slice mining of steeply dipping ore bodies *J. Fundamental and Applied Mining Science* Vol 4 pp 32–36
- [7] Baryshnikov VD and Gakhova LN 2015 Selection of efficient flow sheets for initial cutting in top-down mining in Internatsionalny mine *Journal of Mining Science* Vol 51 No 6 pp 1165–1172
- [8] Kurlenya MV, Baryshnikov VD and Gakhova LN 2012 Experimental and analytical method for assessing stability of stopes *Journal of Mining Science* Vol 48 No 6 pp 609–615
- [9] Bokiyy IB, Zoteev OV, Pul VV and Pul EK 2017 Selection of basic data for numerical modeling of rock mass stress state in the Mirny Mining and Processing Works, ALROSA Group of Companies *J. Fundamental and Applied Mining Science* Vol 4 pp 32–36
- [10] Kazeev AA, Izakson VYu and Zvonarev NK 1995 *Thermal Geomechanics of Diamond Deposits* Novosibirsk: Nauka (in Russian)
- [11] Konovalenko VYa 2012 *Handbook on Physical and Mechanical Properties of Diamond Deposit Rock Mass in Yakutia* Novosibirsk: SO RAN (in Russian)
- [12] Iudin MM 2007 Initial stress state of kimberlite deposits *Nauka i Obrazovanie* No 3 pp 37–39