

Modeling a Stress Condition of Ore Massif in the Process of Bauxite Deposits Development in the Mines of «Sevuralboksitruda»

N I Kosukhin ^{1,a}, D V Sidorov ^{1,b}, L B Gil ^{2,c}

¹ Saint-Petersburg Mining University 199106 St. Petersburg, V.O. 21st line, house 2, Russia

² Tomsk Polytechnic University 634050 Tomsk, Lenina prospect 30, Russia

E-mail: ^a nikolay.kosuhin@uralkali.com, ^b sidorov-post@yandex.ru, ^c gileno@mail.ru (corresponding author)

Abstract. The publication examines the problems of concentrator of elevated tension formation in pillars and ore massif. The article presents the results of modeling the stress state of interchamber pillars and ore deposits, using specialized geomechanical software PRESS 3D URAL. In the process of numerical experiments, it was found that the increase of natural flexibility in pillars leads to a decrease of normal stresses in comparison with the variant of a stiff scheme. If interchamber pillar involves different varieties of ores, there is a redistribution of stress on the site with more stiff ores. The article shows that the stress state control of interchamber pillars and ore massif in conditions of OJSC «Sevuralboxitruda» can be achieved by drilling relief holes.

Introduction

Forecasting the stress state of the rock mass is a very important task to ensure the safety of mining operations for many mining enterprises. [1-8]. This is due to the fact that at present depths of development in the zone of stope influence there is a significant change and redistribution of the stress field. A significant increase in tension at the approach of the front of the treatment works is experienced by areas with a lower capacity of the ore body and its greater strength. A significant tension increase in process of approaching the stopping front get areas with less thickness and greater strength of ore deposits. The increase in normal stresses, acting in massif, in areas with more strength varieties of bauxite ore, determines their ability to accumulate significant elastic energy. At the same time, in the areas of the ore deposit, represented by less strength varieties of ores, as a rule, there is a process of active cracking, fracturing, which indicates a gradual withdrawal of latter from under the load and its redistribution to neighboring stronger areas. The situation becomes more complicated in the case of using room and pillar development systems. This problem is particularly relevant for mining enterprises, developing Severouralsk bauxite basin (OJSC «Sevuralboksitruda») in complex geological, mining and technical, geodynamic conditions.

Specialized geomechanical software PRESS 3D URAL [9-13] allows to solve spatial elastoplastic problems of geomechanics and can be used to identify the regularities of stress distribution in the mining-induced zones of ore deposit and pillars, as well as to determine the optimal parameters of preventive measures to prevent rock bumps and other geodynamical events.

Research objective

The aim of the study is to assess the stress state of the ore mass under different loading regimes of interchamber pillars in the process of underground mining of ore deposits of complex geological structure to improve the efficiency of mines operation at great depths.



Methods

Software PRESS 3D URAL allows to edit the source of mining and graphic documentation, to carry out numerical and analytical calculations, as well as to process the results. The software is developed in the system of visual programming Delphi Pro and allows with a high degree of automation to form a source database, including creation of model structural elements, initialize their properties: depth, thickness, physical-mechanical characteristics, tectonic dislocation characteristics and parameters of relief holes in study area.

Numerical-analytical block includes algorithms, which implement various integro-differential calculation methods, containing a significant amount of cyclic structures. The processor block of the PRESS 3D URAL software, allows to calculate stresses with the cumulative account of a wide range of mining-geological and mining-technical factors: mined-out spaces and pillars arbitrary in size and configuration, arbitrary location of pillars relative the boundaries of mined-out space, parameters of tectonic disturbances and thickness of relief slit. Setting of boundary conditions is carried out by specifying the values of loads, removed from the sole of excavation. The influence of this interaction on the mining-induced zone is taken into account by introducing the displacement parameter q , corresponding to the linear approximation of the stresses, acting on the excavation sole.

Processing unit of calculation results (stresses, strains, displacements, rock-bump hazard zones, allocation of rock-bump hazard zones within the ore deposit and destruction zones on the planes of tectonic fault, the parameters of relief holes) using technology of export results in a modern graphics visualization systems (AutoCad, Serfer, CorelDraw, etc).

To assess the effect of natural and man-made flexibility of ore interchamber pillars on their stress-strain state, numerical experiments were performed for the scheme of the chamber-column development system (with open developed space), presented in figure 1.

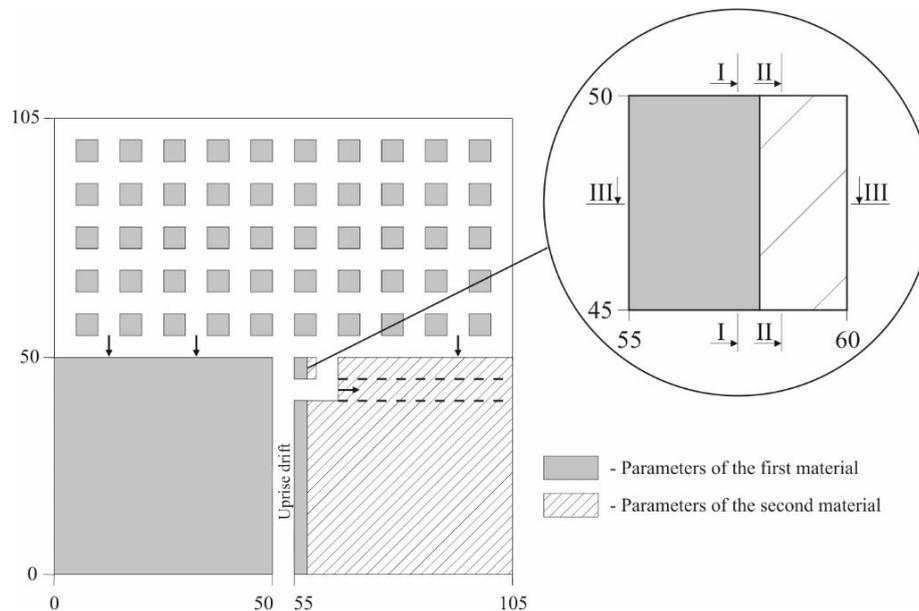


Figure 1. Basic design scheme

The initial data of the computational models, characterizing the possible combinations of the studied parameters, are given in table 1. To study the influence of the spatial configuration of ore deposit boundary part contour on its stress state, the conditions of model 1 were accepted.

Table 1. Initial data for computational models

Model	Parameters of the first material				Parameters of the second material				Note
	m_d , m	E_d , MPa	E_r , MPa	Δ_h , m	m_d , m	E_d , MPa	E_r , MPa	Δ_h , m	
1	0.5	$6.5 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	0.5	$6.5 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	Rigid scheme
2	6.0	$0.6 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	6.0	$0.6 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	Pliable scheme
3	6.0	$0.6 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	2.0	$1.5 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	Rigid-pliable scheme
4	6.0	$0.6 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	2.0	$1.5 \cdot 10^4$	$3.0 \cdot 10^4$	0.01	Rigid-pliable scheme with relief holes
5	6.0	$0.6 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	2.0	$1.5 \cdot 10^4$	$3.0 \cdot 10^4$	0.03	
6	6.0	$0.6 \cdot 10^4$	$3.0 \cdot 10^4$	0.00	2.0	$1.5 \cdot 10^4$	$3.0 \cdot 10^4$	0.05	

where m_d – thickness of ore deposits, m;

E_d – modulus of elasticity of ore Deposit, m;

E_r – modulus of elasticity of rock, m;

Δ_h – thickness of the loading slot, m.

Results

The results of numerical calculations of dimensionless additional stresses, acting in the boundary part of the ore deposit and interchamber pillar, are shown in figure 2. The results of numerical experiments for the conditions of models 1-6 are shown in figures 3-4. Analysis of the results of numerical evaluation of interchamber pillar stress state, shown in figures 3-4, allows us to make the following conclusions.

An increase in natural flexibility of interchamber pillar due to an increase in its power and (or) a decrease in strength of the ore (figure 3, b) leads to a decrease in normal stresses, acting in it by 1.4 times compared to the variant of the rigid scheme (figure 3, a). In the case where the inter-chamber pillar is composed of different types of ores in strength (figure 3, c), there is a redistribution of stresses on the site with more rigid ores, while several unloading adjacent areas of the pillar. The value of additional loading on rigid section is an average of 20% (figure 3, b) compared with the variant, characterizing the uniform strength of interchamber pillar (figure 3, a). At the same time, the value of additional loading of rigid sections in the interchamber pillar will increase as width of rigid section decreases. A significant reduction of operating in pillar stresses can be achieved by giving the target man-made compliance (for example, by drilling discharge wells).

Giving the interchamber pillar additional man-made flexibility, leads to a significant decrease in stresses in it (figure 4). Control of the stress state of interchamber pillar can be carried out by changing the thickness of the man-made gap (parameters of relief holes). The results of the calculation show that the reduction of stresses in the areas of increased stiffness to the average level is achieved with the thickness of the man-made slot $\Delta_h = 0.03$ m.

Significant practical experience, focused on the unloading of elevated stress concentrator in the mines of «Sevuralboksitruda» shows that when the thickness of the man-made gap is about 0.03 m and a diameter of relief holes amount 0.105 m, location of relief holes in the gap need to be done through two diameters of holes (0.2 m).

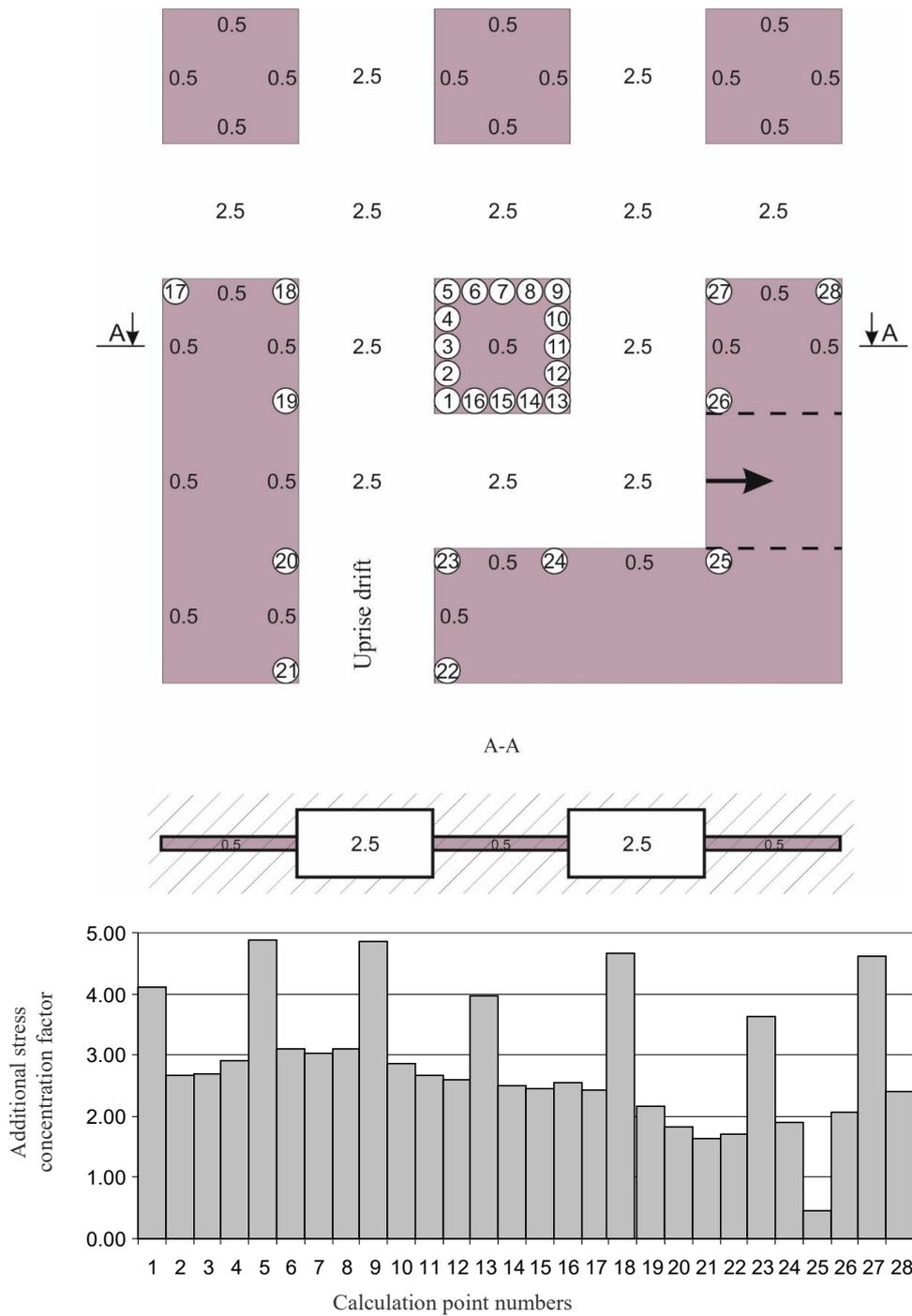


Figure 2. Results of stress state evaluation of ore deposit taking into account the spatial configuration of the boundary part of the deposit

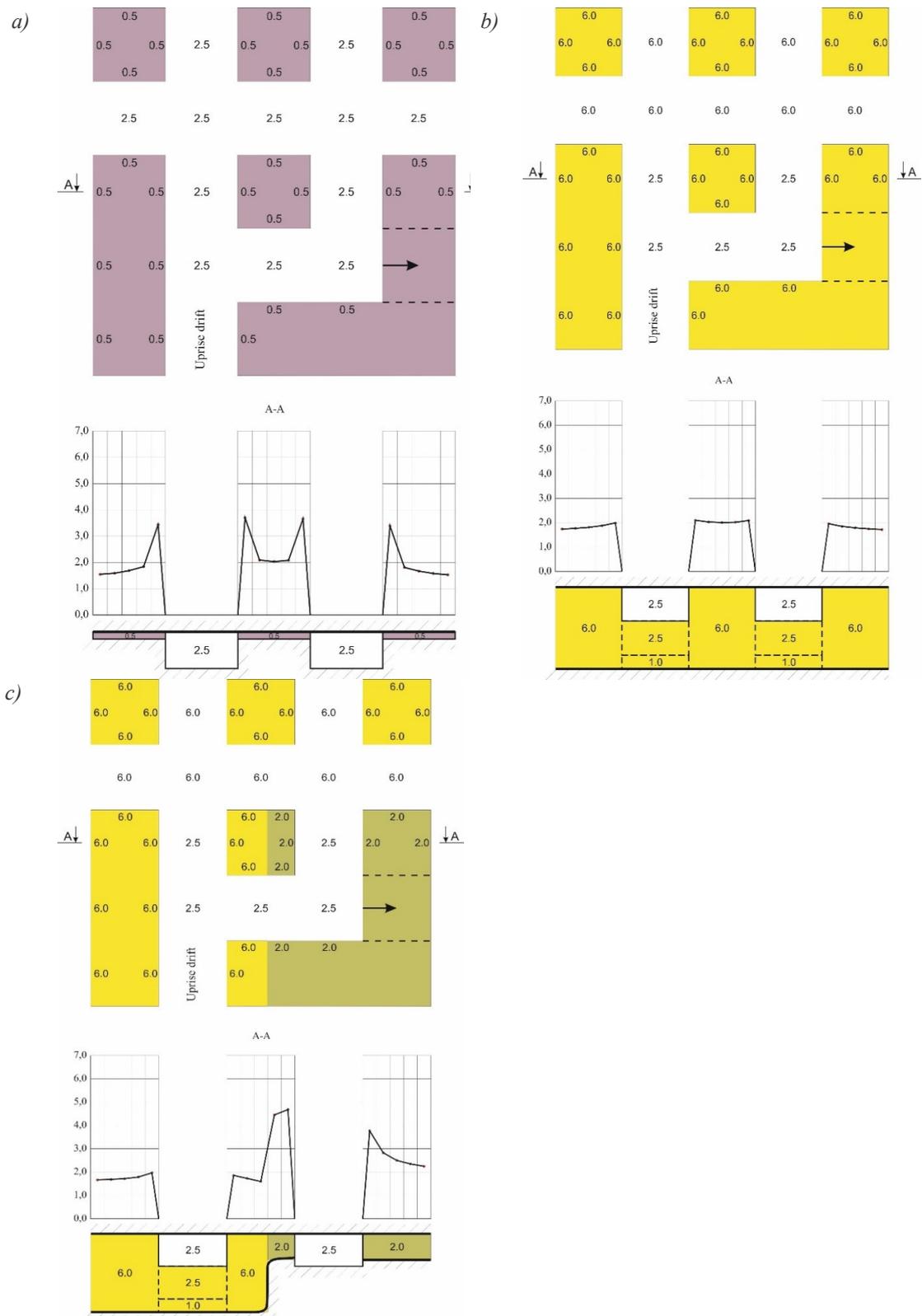


Figure 3. Results of stress state evaluation of the interchamber pillar for reference conditions of models 1-3: a – rigid scheme; b – pliable scheme; c – rigid-pliable schem

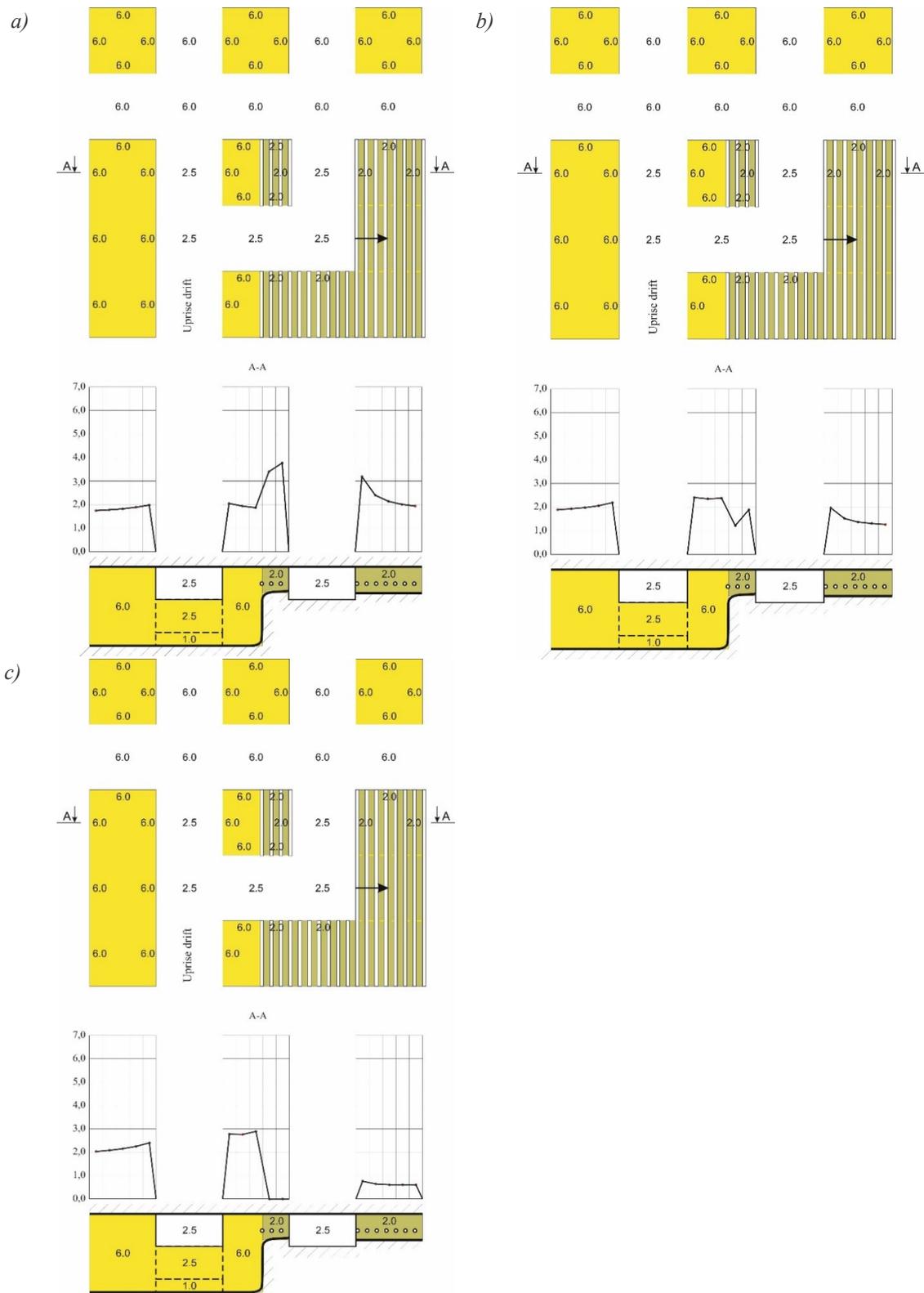


Figure 4. Results of stress state evaluation of the interchamber pillar for models 4-6: a – when $\Delta_h = 0.01\text{ m}$; b – when $\Delta_h = 0.03\text{ m}$; c – when $\Delta_h = 0.05\text{ m}$

Conclusion

As a result, of the performed studies, the regularities of changes in the stress state of interchamber pillars were established, taking into account the influence of various geological and mining factors.

An increase in natural flexibility of interchamber pillar leads to a decrease in normal stresses, acting in it by 1.4 times compared to the variant of the rigid scheme. In the case where the interchamber pillar is composed of different types of ores in strength, there is a redistribution of stresses on the site with more rigid ores, while several unloading adjacent areas of the pillar. The value of additional loading on rigid section is an average of 20% compared with the variant, characterizing the uniform strength of interchamber pillar. Giving the interchamber pillar additional man-made flexibility, leads to a significant decrease in stresses in it. It is recommended to use relief holes to control the stress state of the interchamber pillars. For the operating conditions of mines of «Sevuralboksittruda» it can be recommended drilling relief holes every 0.2 m.

Similar qualitative regularities of stress-strain state of interchamber pillars were identified as a result of widespread mining experimental studies, carried out on ores of Dzhezkazgan and Mirgalimsay, which is developing a copper-nickel deposits, using chamber-and-pillar system development. The reliability of the developed modified method of integral equations was confirmed by comparing the results of the numerical experiment with the results of mining and experimental work (mine "Kalinskaya" OJSC "SUBR"), as well as with experimental data of laboratory studies of the stress-strain state of interchamber pillars, using equivalent materials in the certified laboratory of rock modeling of the Scientific research center of geomechanics and problems of mining production in St. Petersburg mining University.

References

- [1] V.A. Eremenko, Kontrol geomexanicheskogo sostoyaniya geologicheskoy sredy` pri otrabotke Sheregeshevskogo mestorozhdeniya / V.A.Eremenko, A.A.Eremenko, V.N.Filippov i dr. // Gornyj informacionno-analiticheskij byulleten. 12 (2007) 155–169.
- [2] Yu.P Galchenko., V.A. Eremenko, A.V. Myaskov, M.A. Kosyreva, Solution of geocological problems in underground mining of deep iron ore deposits // Eurasian Mining. 1 (2018) 35–40.
- [3] A.P. Gospodarikov, Y.N. Vykhodtsev, M.A. Zatsepin, Mathematical modeling of seismic explosion waves impact on rock mass with a working / Journal of Mining Institute, 226 (2017) 405 – 411.
- [4] N.I. Kosukhin, D.V. Sidorov, I.I. Beloglazov, V.Yu. Timofeev, Assessment of stress-strain and shock bump hazard of rock mass in the zones of high-amplitude tectonic dislocations // IOP Conf. Series: Earth and Environmental Science, 224 (2019) 1-5, DOI: 10.1088/1755-1315/224/1/012014.
- [5] T. Ponomarenko, I. Sergeev, Quantitative methods for assessing levels of vertical integration as a basis for determining the economic and organizational sustainability of an industrial corporation // Indian Journal of Science and Technology, 9 (20) (2016).
- [6] I.Yu. Rasskazov, Geodinamicheskoe sostoyanie massiva porod Nikolaevskogo polimetalliche-skogo mestorozhdeniya i osobennosti proyavleniya udaroopasnosti pri ego osvoenii / I.Yu. Rasskazov, B.G. Saksin, V.I. Usikov, M.I. Potapchuk // Gornyj zhurnal. 12(2016) 13–19.
- [7] I.Yu. Rasskazov, Geomexanicheskaya ocenka usloviy razrabotki glubokix gorizontov polimetallicheskogo mestorozhdeniya «Yuzhnoe» / I.Yu. Rasskazov, G.A. Kursakin, M.I. Potapchuk // Fiziko-texnicheskie problemy` razrabotki polezny`x iskopaemy`x. 5 (2012). 125–134.
- [8] V.S. Koshkina, A.A. Serova, V.Y. Timofeev, Environmental-Toxicological Characteristics of Waters and Their Sources at Magnitogorsk With the Its Iron and Steel Industry //IOP Conference Series: Materials Science and Engineering. – IOP Publishing, 142(1) (2016) 012117.
- [9] D.V. Sidorov, Prognozirovanie udaroopasnosti tektonicheskoi narushennogo rudnogo massiva na glubokix gorizontax Nikolaevskogo polimetallicheskogo mestorozhdeniya / D.V. Sidorov, M.I. Potapchuk, A.V. Sidlyar // Zapiski Gornogo instituta. 234 (2018) 604–611. DOI: 10.31897/PMI.2018.6.604.
- [10] D.V. Sidorov, T.V. Ponomarenko, The development of a software suite for predicting rock bursts within the framework of a system for ensuring geodynamic safety of mining operations // 17th International Multidisciplinary Scientific GeoConference SGEM 2017, www.sgem.org, SGEM 2017 Conference Proceedings, ISBN 978-619-7408-02-7 / ISSN 1314-2704, 29 June - 5 July, (2017), Vol. 17, Issue 22, 633-638 pp, DOI: 10.5593/sgem2017/22/S09.079.

- [11] V.Y. Timofeev et al. The Mutual Effect of Reciprocally Moving Geokhod and Geological Environment Studied by the Discrete Element Method in Software PFC3D 5.00 //IOP Conference Series: Materials Science and Engineering. Vol. 142: Innovative Technologies in Engineering.—Bristol, 2016. – IOP Publishing, 142(2016) 12126.
- [12] Z. Zhang, H. Shimada, T. Sasaoka, W. Kai, Study on the overlying strata movements and stability control of the retained goaf-side gateroad // Memoirs of the Faculty of Engineering, Kyushu University.76 (2) (2016) 1–17.
- [13] S.V. Kovshov, D.A. Iconnicov, Growing of grass, radish, onion and marigolds in vermicompost made from pig manure and wheat straw // Indian Journal of Agricultural Research. – 51 (4)(2017).