Prediction of the Geomechanical State of the Fixed Ground Basis of a Mining Building

Mikhail Sokolov^{1,*}, and Mikhail Karablin²

¹T.F. Gorbachev Kuzbass State Technical University, Kemerovo, Russian Federation

²Kuzbass Head Institute on designing of coal mining and coal processing enterprises (OAO "KuzbassGhiproShakht"), Kemerovo, Russian Federation

Abstract. The results of engineering and geological surveys to the ground base of a mining and technical building, composed of man-made filled-up ground, are presented. A simulation of the stress-strain state of a fixed ground base was carried out. The analysis of changes in the geomechanical state of the ground massif as a result of injection compaction is presented, on the basis of which recommendations are given on adjusting the parameters of the injection technology.

1 Introduction

At working on the development and mining of mineral resources, specific attention is paid to technological safety issues, including non-emergency exploitation of buildings and structures. Mining buildings and facilities are most responsible objects that are subject to various types of negative factors, including the dynamic effects from traffic of mining machine and mass explosions. Separate categories of buildings and structures can be located on bulk ground bases from overburden and technogenic sediments with constantly changing hydro-geological regime. As a result of the impact of the combination of these factors, ground bases are subject to the formation of weak and water-saturated zones with low deformation and strength properties. To increase the stability of ground bases various methods of fixing are used, of which the methods of pressure injection and electrochemical fixing are widespread [1-4].

Along with the development of methods for fixing of ground bases, the issue of determining rational ranges of their technological parameters is topical. Existing analytical methods quite accurately determine the parameters of fixing, however, they do not take into account the structural heterogeneity of the massif, are based on empirical dependencies and have limited ranges of physical and mechanical properties [5-7]. More accurate parameters are obtained when integrating numerical modeling and forecasting methods based on basic and local models which are able to take into account the structural features of ground base, the presence of anomalous zones with low physic mechanical properties [8-10].

* Corresponding author: smv.ad@kuzstu.ru

starting material is siltstone, argillite, and "burnt rock". The thickness of the layer ranges from 2.2 m to 2.4 m.

IGE # 2 has a distinctive feature in the form of a wedge-shaped occurrence with falling in two planes in accordance with the above engineering-geological sections (Fig. 2).

Fig. 2. Engineering geological sections: 1 ... 3 – numbers of engineering geological elements.

The main physic and mechanical properties were determined under laboratory conditions and are shown in Table 1.

Table 1. Summary table of soils mechanical properties.

	The name of the physic and mechanical properties	Units	The number of engineering geological element		
			IGE #1	IGE #2	IGE #3
1	Natural density ρ : - in natural state - in wetted state	g/cm ³	1.65 –	1.95 1.75	2.05 1.95
2	Angle of internal friction φ : - in natural state - in wetted state	deg.	20 –	24 20	31 24
3	Coupling C : - in natural state - in wetted state	kPa	7 –	19 10	28 25
4	Deformation module E : - in natural state - in wetted state	MPa	10 –	20 12	24 20

As part of the work, computer geomechanical modeling was carried out on the basis of the Alterra software package of the Russian developer InzhProjectSroy. The study of changes in the geomechanical state is based on local models of ground base, implemented with using the finite element method [11-13], in zone with the most characteristic form of bedding (Fig. 3, a).

The model has a basic sizes of 38×18.2 m, includes 3 layers of technogenic deposits according to the presented sections and 3 band foundations at a distance of 6 m from each other. Each foundation is loaded with a concentrated force P and transmitting force to the sole 1.2 m wide, located at a depth of $d_f = 3.2$ m. The foundations are made of reinforced concrete with the following properties: density $\rho_f = 2500$ kg/m³, deformation module $E_f = 2000$ kPa, Poisson's ratio $\nu = 0,15$. The physic mechanical properties of IGE are taken as for the wetted state, which simulates a change in the hydrogeological mode. The model has

limitations and boundary conditions for lateral and lower boundaries [14]. The calculation was performed in the linear-plastic stage with a task of no more than 500 iterations for non-linear deformation and no more than 500 iterations for plastic shear deformations [15].

Fig. 3. Schemes of the local model and fixing of the ground base: 1 – the ground base; 2 – fixing zone; 3 – injectors.

To study the effect of fixing the ground base by pressure injection of cement-sand mortars, a scheme was adopted for fixing the base for a building on band foundations with internal load-bearing walls. The depth of immersion of the injectors, their location and the parameters of the pressure injection were taken according to the project of OOO NooCenter (Fig. 3, b).

3 Results

The results were analyzed along the characteristic vertical axes z_1 , z_2 , and z_3 located along the axes of symmetry of each foundations.

Primary simulation results in the form of graphs of vertical σ_z and horizontal σ_x stresses are presented in Fig. 4.

The graphs of vertical stresses σ_z monotonously decrease with increasing depth of the massif, and their magnitude decreases with the introduction of zone of fixing into the calculation. Not characteristic is the area of stabilization of stresses σ_z in the interval $z_2 = 5.5...10.0$ m. Horizontal stresses σ_x along the z_1 axis are distributed with the formation of a zone of minimum values in the interval $z_1 = 5.0...7.5$ m. However, the stresses σ_x along the z_2 and z_3 axes are distributed only within the limits of IGE # 2, also at a fixing massif negative values of stresses are formed.

The second stage of the analysis aims to assess the regularities of the total ε_z and plastic ε_{zp} vertical deformations shown in Fig. 5.

The deformations of ε_z along the z_1 axis have similar outlines with stress graphs, with the exception of the peak of deformations in the interval $z_1 = 4.0...5.0$ m, which is retained in fixing massif, but has a smaller amplitude. Along the z_2 axis, the ε_z deformations are distinguished by a pronounced drop in the values at the boundary of the layers IGE # 2 and # 3, which is not eliminated in fixing massif. On the interval $z_2 = 3.8...4.9$ m, the values of ε_z increase significantly. The presence of "a jump" of the deformations at the boundary of the layers is also characterized by the $\varepsilon_z(z_3)$ graph, beyond which the calculated values monotonously decrease.

The manifestation of plastic deformations ε_{zp} is characteristic only at a depth of up to 6 m, only within the limits of IGE # 2 (of a weak, not packed layer), with it's the distribution graphs along all axes have a area of maximum. When fixing, the greatest effect is observed for the z_1 and z_3 axes, where the ε_{zp} values decrease by 2 and 1.5 times, respectively.

Fig. 4. Dependence of vertical σ_z (a) and horizontal σ_x (b) stresses from the depth of the model z , with: 1 – the natural massif; 2 – the fixed massif.

Fig. 5. Dependence of the full ε_z (a) and plastic ε_{zp} (b) vertical deformations from the depth of the model z , with: 1 – the natural massif; 2 – the fixed massif.

The negative is the increase in deformations ε_{zp} along the z_2 axis by an average of 14 %, with an increase of the zone of plastic deformations by 0.2 m in depth. Thus, the results of the evaluation of the deformed state indicate a lack of effectiveness of the adopted fixing scheme for the central foundation.

4 Conclusion

According to the results of the analysis the effectiveness of the fixing of the ground bases was generally confirmed, manifested in the form of a significant decrease in vertical deformations and stresses. Identified the need to change the scheme of fixing of the central foundation, because along the z_2 axis both complete and plastic deformations increase, and horizontal stresses have negative values at the interface of layers 2 and 3. With regards to the foundation along the z_3 axis, an assumption was made about the possible displacement of the inclined fixing zone under the action of loads. Due to the increased rigidity and the presence of a metal injector in the zone of fixing, the cut across the cross section is not considered.

Based on the results of geomechanical modeling, it is recommended to change the scheme of fixing the central foundation from inclined to the vertical location of the wells.

Thus, an increase in time without emergency operation of buildings during mining operations will be achieved.

References

1. M. N. Ibragimov, Soil Mech. Foun. Engin., **50**, 200 (2013)
2. M. N. Ibragimov, Soil Mech. Foun. Engin., **52**, 100 (2015)
3. Shao-Chi Chien, Fu-Chen Teng, Chang-Yu Ou, Acta Geotech., **10**, 813 (2015)
4. Flora, S. Gargano, S. Lirer, L. Mele, Geotech. Geolog. Engin., **9**, 650 (2017)
5. S. M. Prostov, N. Yu. Nikulin, J. of Mining Science, **51**, 908 (2015)
6. V. Azarov, M. V. Kurlenya, A. V. Patutin, S. V. Serdyukov, J. Min. Sci., **51**, 1063 (2015)
7. T. V. Lobanova, S. V. Moiseev, J. Min. Sci., **45**, 227 (2009)
8. G. Protosenya, M. A. Karasev, Soil Mech. Foun., **51**, 53 (2014)
9. L. A. Strokova, Soil Mech. Foun. Engin., **46**, 117 (2009)
10. D. Mujah, K. S. Siaw, S. Tasnim, Soil Mech. Foun. Engin., **52**, 317 (2016)
11. S. G. Bezvolev, Soil Mech. Foun. Engin., **45**, 77 (2008)
12. Z. G. Ter-Martirosyan, A. S. Abdulmalek, Soil Mech. Foun. Engin., **44**, 195 (2007)
13. D. M. Shapiro, N. N. Mel'nichuk, Soil Mech. Foun. Engin., **44**, 62 (2007)
14. S. M. Prostov, M. V. Sokolov, Taishan Acad. Forum - Project Min. Dis. Prev. Cont., **350**, 122 (2014)
15. S. M. Prostov, M. V. Sokolov A. V. Pokatilov, Inter. J. Ap. Eng. Res., **10**, 45297 (2015)