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Experimental assessment of stresses in enclosing rock mass of Aikhal mine

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Abstract. Experimental assessment of stresses has been carried out in the vicinity of temporary roadway outside the influence zone of stoping in Aikhal mine. The analysis of the research results shows that the values of stresses experimentally found in adjacent rock mass at the depth of mining are local and cannot be used for correct determination of stress state of an intact rock mass.

1. Introduction

Natural stress state of rock mass is a certain factor of power in assessment of mining conditions, stability of underground excavations and support design. Using stress distribution hypothesizes by Dinnik or Heim as boundary conditions in numerical modeling of rock mass stress state is not always correct and requires instrumental confirmation. The only one reliable method of estimating natural stresses in tectonically active areas is experimental research.

Currently Aikhal mine, ALROSA, extract mineral reserves under the open pit bottom at a depth of 300–400 meters in rhomb-shaped stopes arranged in staggered order, in descending cut-and-fill with cemented backfill. Optimized location and support of temporary roadways in rock mass enclosing complex morphology ore body requires detail justification [1]. The experimental assessment of stresses, given lack of information on initial stress state, is a live issue in Aikhal kimberlite pipe mining.

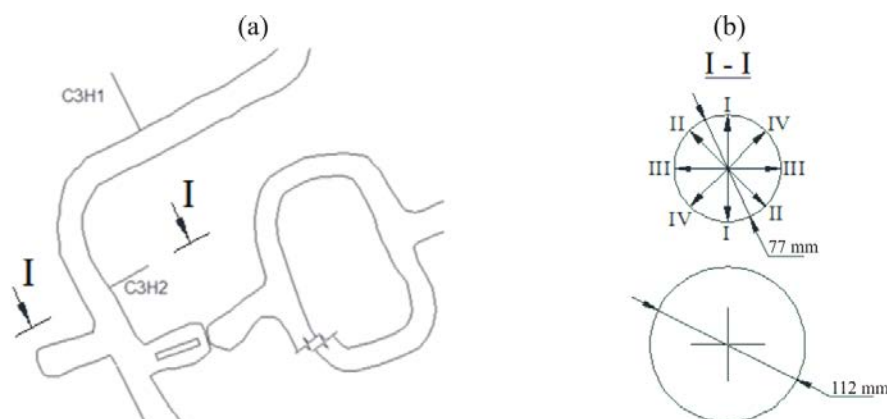


Figure 1. (a) Layout of SMP on level ± 0 m and (b) boreholes with orientation of deformometer measuring directions.

2. Research methods and approaches

In 2017 the first cycle of stress state assessment was carried out using parallel borehole method. This method [2] and technical devices for its implementation [3] were developed at the Chinakal Institute of Mining SB RAS. The designed automated measurement system was successfully trialed in actual stress-strain analysis in salt rock mass in Mir mine [4].

Measuring and perturbing boreholes were drilled by Husqvarna drilling machine with diamond boring bit $\varnothing 77$ mm and $\varnothing 112$ mm. This small size machine drills holes to 2.5 m long. The installation depth of the deformometer was set based on the data of video filming on the borehole wall condition using a video probe, in order to avoid damage or cracking in the hole walls in the measurement interval.

3. Results and discussion

The plot of radial displacements of walls in the measuring borehole under step-by-step loading of walls in the perturbing borehole subjected to uniform pressure at SMP 1 is presented in Figure 2. The experimental data analysis confirms that the dependence of radial displacements on the loading pressure is linear and there are no residual displacements after unloading of the perturbing borehole. The afore-said allows the elasticity theory apparatus to be used to estimate deformation properties and stresses in rock mass.

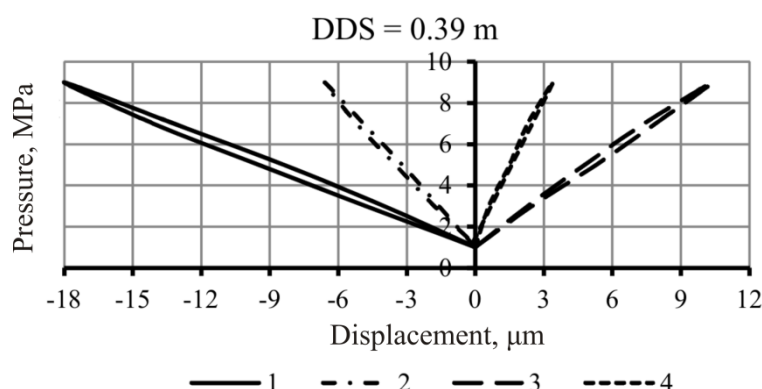


Figure 2. Radial displacements of walls in the measuring borehole under loading and unloading of the perturbing borehole.

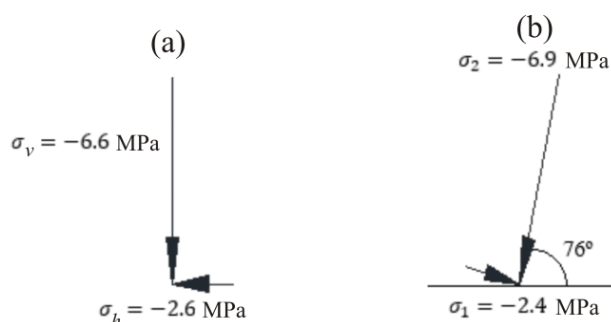


Figure 3. Directions and values of (a) components and (b) quasi-principal stresses.

Table 1. Stresses (MPa) at SMS 1.

DDS, m	σ_v	σ_h	τ_{vh}	σ_1	σ_2	Γ_{σ_2} deg
0.39	-6.6	-2.6	1.1	-2.4	-6.9	76

Comments: σ_v —vertical stress component; σ_h —horizontal stress component; τ_{vh} —shearing stress component; σ_1, σ_2 —quasi-principal stresses in vertical plane perpendicular to the borehole axis; Γ_{σ_2} —angle between the major quasi-principal stress and the horizon.

The resultant stresses determined at the depth of the deformometer setting up (DDS) of 0.39 m from the excavation walls at SMP 1 are presented in Table 1 and Figure 3.

In accordance with the calculations, the vertical component of stress on level ± 0 m under overlying rock weight is $\gamma H = 10$ MPa. The concentration coefficient of the vertical component at DDS = 0.39 m from the numerical calculations of stress distribution around the excavation was $K = 1.62$. Taking that coefficient into consideration, the theoretical value of the vertical stress component is $\sigma_v^t = 10 \text{ MPa} \times 1.62 = 16.2 \text{ MPa}$ and it sufficiently (by 2.5 times) exceeds the experimental value $\sigma_v = 6.6$ MPa. This means that rocks nearby the excavation wall are unloaded. So we cannot correctly interpret experimental data and determine stress state of intact rock mass.

After that the enclosing rock mass stresses were measured at SMS 2 at DDS of 0.6 m, 1.1 m, 1.77 m and 2.44 m. The curves of the measuring borehole wall displacements in radial direction under loading–unloading of the perturbing borehole are plotted in Figure 4.

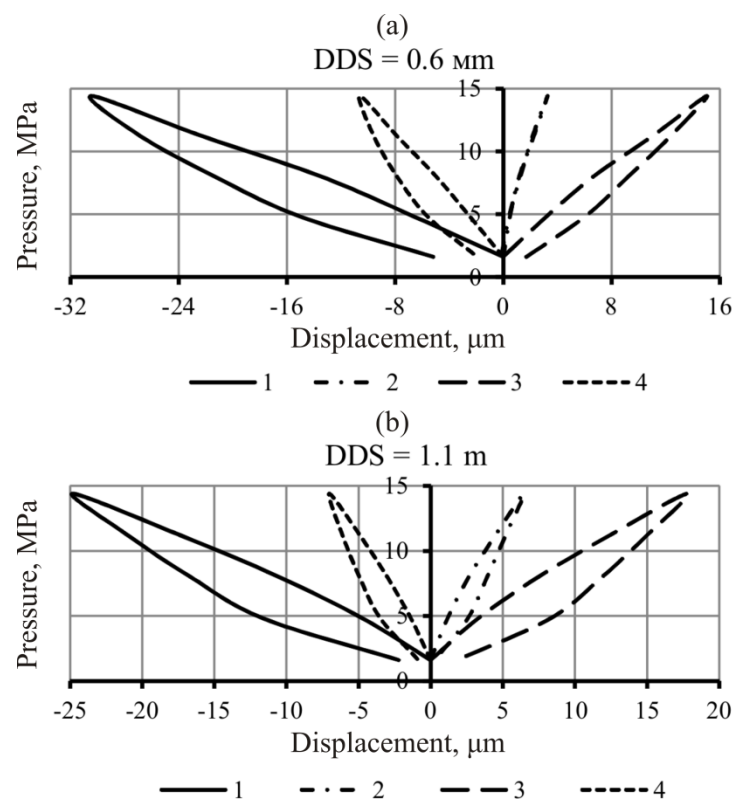


Figure 4. Radial displacement of walls in the measuring borehole under loading–unloading of the perturbing borehole at (a) DDS = 0.6 m and (b) DDS = 1.1 m.

The values of stresses (MPa) determined in the experiment are given in Table 2 and Figure 5.

Table 2. Stresses (MPa) at SMS 2.

DDS, m	σ_v	σ_h	τ_{vh}	σ_1	σ_2	Γ_{σ_2} , deg
0.6	−12.8	−3.4	2.6	−2.7	−13.5	76
1.1	−16.8	−7.2	1.3	−7.0	−16.9	82
1.77	−17.1	−6.0	−2.3	−5.5	−17.5	79
2.44	−12.4	−3.4	−4.0	−1.8	−13.9	69

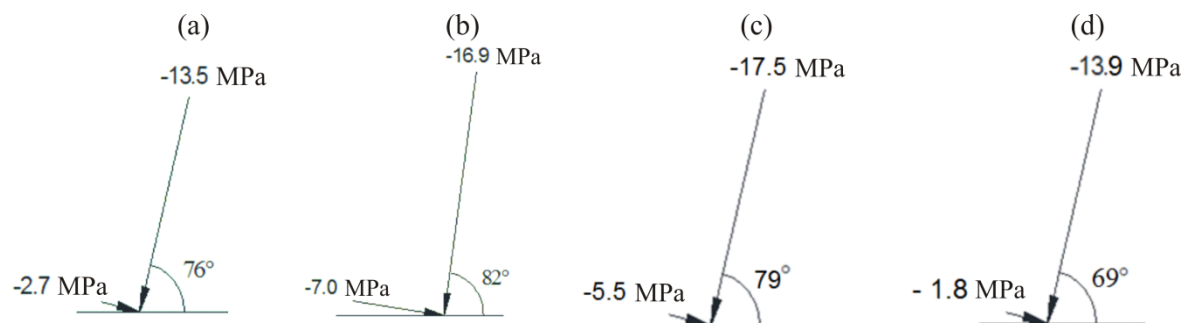


Figure 5. Directions and values of quasi-principal stresses at SMS 2: (a) DDS = 0.6 m; (b) DDS = 1.1 m; (c) DDS = 1.77 m; (d) DDS = 2.44 m.

The concentration coefficients of the vertical stresses σ_v at the deformometer depth from the excavation wall of 0.6 m, 1.1 m, 1.77 m and 2.44 m are 1.66, 1.58, 1.43 and 1.34 respectively. The theoretical values of the vertical stress component caused by the overlying rock weight σ_v^t are -16.7 MPa , -15.9 MPa , -14.3 MPa and -13.4 MPa . The comparison of the theoretical and experimental stress components shows that at DDS = 0.6 m, the experimental value $\sigma_v = -12.8 \text{ MPa}$ is 1.3 times smaller than the theoretical stress $\sigma_v^t = -16.7 \text{ MPa}$; at DDS = 1.1 m the experimental value $\sigma_v = -16.8 \text{ MPa}$ is 1.05 times higher than the theoretical $\sigma_v^t = -15.9 \text{ MPa}$; at DDS = 1.77 m $\sigma_v = -17.6 \text{ MPa}$ is 1.23 times higher than $\sigma_v^t = -14.3 \text{ MPa}$; and at DDS = 2.44 m $\sigma_v = -12.4 \text{ MPa}$ is 1.08 times smaller than $\sigma_v^t = -13.4 \text{ MPa}$. Such discrepancy of the theoretical and experimental data is caused by partial softening of rock mass nearby the excavation wall because of drilling and blasting. Damage of the borehole walls shown in Figure 6 prove the hypothesis of the softened rock mass.

The values of the horizontal stresses along the excavation axis allow drawing a conclusion that the tectonic stresses are absent. The character of the horizontal stresses agrees with the Dinnik hypothesis best at all.

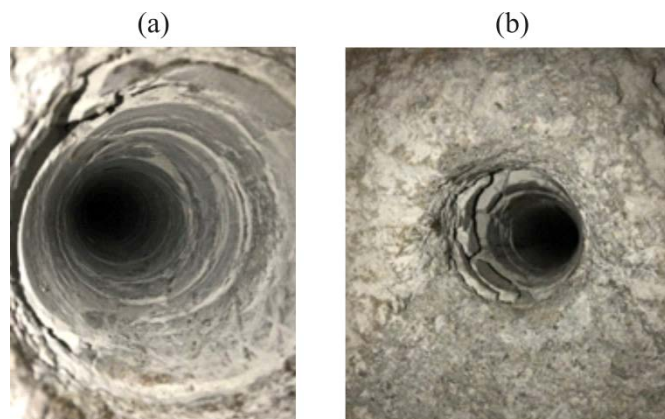


Figure 6. Damage of borehole walls at (a) SMS 1 and (b) SMS 2.

4. Conclusions

The pre-estimation of stress state in intact rock mass proves the absence of the tectonic stresses, and the lateral earth pressure coefficient is 0.5.

The research results show that stresses measured nearby the excavation wall characterize only stress state at the measurement point and not allow stress state assessment in the intact rock mass correctly.

Stress measurements are to be conducted at the distance of softened or partly damaged walls of excavations, outside its influence zone, in order to get correct assessment of natural stress state

parameters of rock mass. Such approach requires using relevant methods of measurements and providing the measurements by drilling.

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