GEOMECHANICS / ГЕОМЕХАНИКА

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PROGNOSIS METHOD OF THE ZONAL FAILURE STRUCTURE PARAMETERS NEAR THE DEEP OPENINGS

A method of mathematical determination of the model parameters of rock mass zone destruction in the conditions of great depths has been developed as a result of experiments with rock samples. The characteristics of zonal destruction have been predicted, the Nikolaevskoye deposit of the Primorsky Territory providing an example. The hierarchical levels of deformation and destruction of rock and a way of transition from a level of the sample to a level of a rock mass are presented as well.

Key words: zonal destruction, high stressed rock mass, the block hierarchical levels, the rock sample.

Метод прогнозирования параметров модели зональной структуры разрушения массива вокруг выработок на большой глубине. Макаров Владимир Владимирович – д.т.н., профессор, Голосов Андрей Михайлович, инженер, кафедра горного дела и комплексного освоения георесурсов Инженерной школы, Ксендзенко Людмила Степановна, к.ф.-м.н., доцент кафедры алгебры, геометрии и анализа Школы естественных наук (Дальневосточный федеральный университет, Владивосток).

Метод определения параметров математической модели зонального разрушения массива горной породы в условиях больших глубин разработан на основе экспериментов с образцами горных пород. На примере массива пород рудника Николаевский Приморского края прогнозируются характеристики зонального разрушения. Для перехода с уровня образца на уровень породного массива вводятся иерархические уровни дефектной среды, моделирующей массив горных пород.

Ключевые слова: зональное разрушение, сильно сжатый горный массив, иерархические уровни, образцы горной породы.

Zonal failure problem and the mathematical model development of this phenomenon is very important task of the up-to-date Geomechanics. Rock mass in condition of high stress can be described as defect media in far from thermodynamical equilibrium conditions [1]. Boundary task about the stress displacement around the opening at high depth can be analyzed as plane and stationary with the destruction of incompatibility, incompressibility and hydrostatic conditions of loading on infinity.

In these assumptions the radial normal stress σ_{rr} and tangential normal stress $\sigma_{\varphi\varphi}$ in rock mass around the circular form opening can be described by the equations [1, 4]:

$$\sigma_{rr}(r)=\sigma_{\infty}\cdot\left(1-\frac{r_0^2}{r^2}\right)-\frac{1}{2r}\cdot\frac{E}{\gamma^{\frac{3}{2}}\ 1-\nu^2}\left[a\cdot J1(\sqrt{\gamma}\cdot r)+b\cdot Y1(\sqrt{\gamma}\cdot r)+c\cdot K1(\sqrt{\gamma}\cdot r)\right]$$

$$\sigma_{\varphi\varphi}(r)=\sigma_{\infty}\cdot\left(1+\frac{r_0^2}{r^2}\right)+\frac{1}{2r}\cdot\frac{E}{\gamma^{\frac{3}{2}}\ 1-\nu^2}\left[a\cdot J1(\sqrt{\gamma}\cdot r)+b\cdot Y1(\sqrt{\gamma}\cdot r)+c\cdot K1(\sqrt{\gamma}\cdot r)\right]-$$

$$-\frac{E}{2\cdot\gamma\cdot\ 1-\nu^2}\left[a\cdot J0(\sqrt{\gamma}\cdot r)+b\cdot Y0(\sqrt{\gamma}\cdot r)-c\cdot K0(\sqrt{\gamma}\cdot r)\right], \quad (1)$$

where σ_{∞} is gravity stress, MPa; r_0 is opening radius; r is distance from the openings center to the measurement place in rock mass; $J0, J1, Y0, Y1, K0, K1$ is Bessel, Neiman and Macdonald functions zero or first order correspondevely; E is Young modules; ν is Poisson ratio; γ, c are the parameters of mathematical model of the zonal failure of high stressed rocks.

Parameter γ can be determined in procedure of statistical analysis of the natural research results of zonal failure process in deposits of Russia (Far Eastern part, Siberia, Donbass) and China. There was determined linear character of dependence between relative distance from opening counter to middle point of the first failure zone and uniaxial strength of the rock:

$$r*/r_0=0{,}0083\sigma_c+0{,}748. \quad (2)$$

Relationship between parameters γ and r^*/r_0 is linear too:

$$\gamma\left(r^*/r0\right)=-10\left(r*/r_0\right)+23, \quad (3)$$

here r^*, m – distance from opening contour to middle point of the first failure zone which have been achieved from experimental data.

Rock mass is shown as hierarchical block media [3, 6, 8, 9]. When the physical character of failure on the neighbor levels are in the same way, the macrodefect size of the lower level can be determined as mesodefect of the correspondevely higher level [3, 8]. So this low is reflected in the conservation shear-tensile character of the rock failure on the neighbor levels of samples and mass in condition of the high stress [5].

Algorithm of the mathematical model parameters determination consists in the next steps:

1. After the rock sample strength researches the limit of strength σ_c, limit of residual strength σ_{res}, Young modules E and Poison ratio ν are determined. Then by using of the formula (3) the emplacement of the first failure zone middle point r^*/r_0 can be find. And after the substitution this data in analytical equation (2) the first correction parameter of the mathematical model γ can be determined.

2. The maximum diameter of the rock sample minerals $d_{\max}$ and maximum mesocrack discloser $h_* \approx d_{\max}$ are determined. Support of these parameters, the minimum half-length of the tensile mesocrack $l_{mezo} \approx 2,5-5\ d_{\max}$. is calculated.

3. On rock sample research deformational curves the parameters of prefailure stage are determined: $E_{sample}^{sourse}, \nu, \delta P$, where E_{sample}^{sourse} = 0,3–0,7 E, $\delta P = \sigma_c - \sigma^*$, and deformations data after the threshold of dilatancy. These parameters are used in the stress intensity factor of the rock sample mesocrack calculation.

4. Determination of the critical half-length of tensile macrocrack in sample by the formula: $l_* = \dfrac{h_* \cdot E}{4\left(1-\nu^2\right)\gamma_1 \cdot \sigma_c}$, and the stress intensity factor of the rock mass is calculated by the formula: $K_I^{mass} = \gamma_1 \cdot \sigma_c^{rec} \cdot \sqrt{\pi l_{meso}^{mass}}$.

5. After that both stress intensity factors of rock sample and rock mass are writing in equation of equality and parameter of the model "C" is determined as result of the calculation.

The developing method had been applied to the problem of zonal failure in ore mine Nikolaevskij (Dalnegorsk, Russia). Forecasting depth of the cracking zone development is shown on Table.

Forecasting depth of the zonal failure development in ore mine Nikolaievsky

Number of failure zone	I	II	III	IV
Relative critical stress of zone formation	1,3	2,3	2,9	3,3
Depth of zone appearance, m	520	920	1160	1320

Amplitude parameter "C" is depending from the modulus of deformation and Poison ratio of the rock mass (Fig. 1).

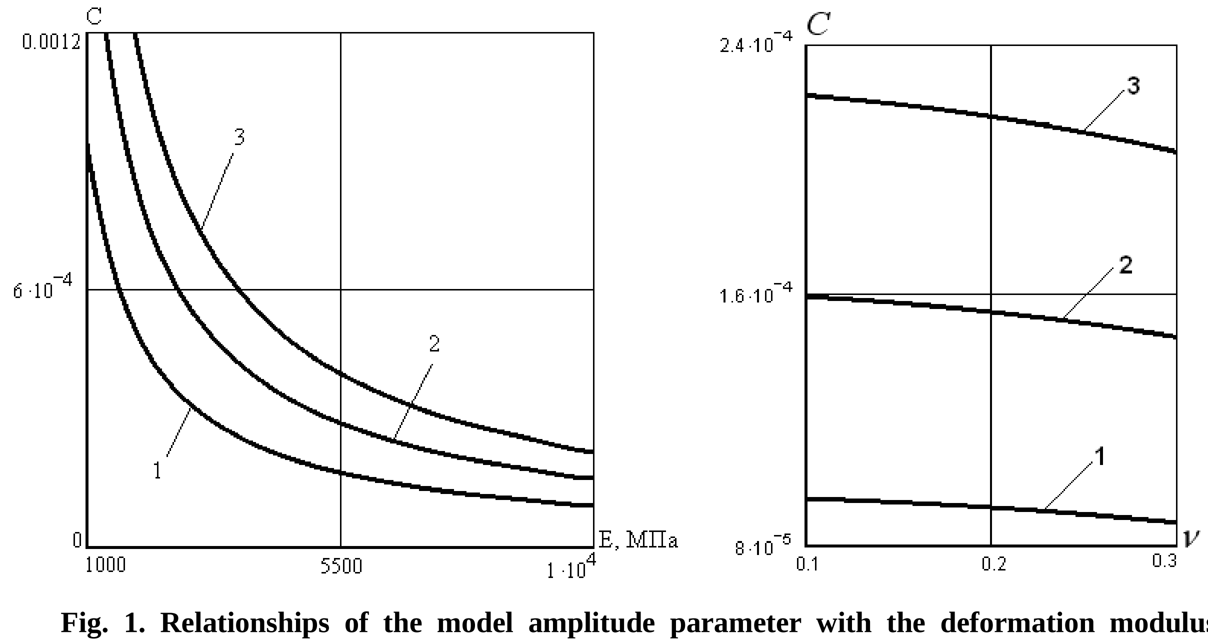

Fig. 1. Relationships of the model amplitude parameter with the deformation modulus *E* and Poison ratio *ν* in condition of the different number of rock mass failure strength: 1 – K_{IC} = 1,5 MPa · m$^{1/2}$, 2 – K_{IC} = 2,0 MPa · m$^{1/2}$, 3 – K_{IC} = 2,5 MPa · m$^{1/2}$

The precision of correlation between theory and experiment have been estimated after comparison the results of native measurement of the radial displacements near the openings on high depth (Nikolaevskij ore mine) with the model calculation results (Fig. 2). There were determined that difference between forecasting and measuring data no more than 50% in the fore radius field around the opening.

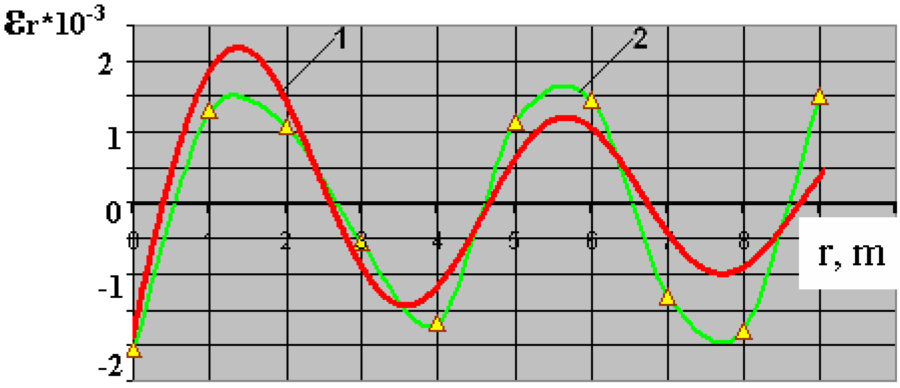

Fig. 2. Comparison between theory (1) and experiment (2) data of radial deformations

Conclusion

The method of mathematical model parameters of zonal failure near the deep openings determination had been developed. A fool quality and good quantity correlation between theory forecasting and experimental research had been achieved.

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