ON ROCK DESTRUCTION ROUND DEEP UNDERGROUND WORKINGS AND ITS INFLUENCE ON THE ROCK PRESSURE VALUE

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This paper treats the stressed-deformed states and stability of equilibrium state of the medium round underground workings of deep bedding are investigated. Notions of stability of state equilubrium of the deformed rigid body are used for the stability workings analysis.

This paper treats the general regularities of mechanical processes near deep underground workings , taking into account the destruction of the rock round them, the procedures of the evaluation of the rock pressure value on timbering and shift of excavation contour value. These values are the input data under the calculation of optimal supported construction (rock timberings). The definition of values is reduced to two stages of the investigation: I - the construction of the behaviour model of rock mass round a deep underground workings, taking into account the peculiarities of rock destruction [1,2] II - mechanical-mathematical analysis of this model from a point of view of a stability theory of the deformed rigid body [1,3,4] .

According to stage I, stressed-deformed state of rock mass round a deep working is defined. The rock mass with built working is simulated by a weightless plane with a hole (plane problem) and by weightless space with spherical or vertical cylindrical workings (space axially symmetric problem), simultaneously on the infinity is effort γh (γ - is a solid weight of upper media, h - is a deepness of the working), p - is a loading distributed uniformly on the contour of the hole and cavity of the radii R_o . As a plasticity condition I takes an equation of media state with friction and linking (Coulomb-Mohr condition):

$$\max\{|\tau_n| - (\sigma_n + H)\} = 0, \qquad (1)$$

where σ_n, τ_n - are the normal and tangential stresses, H - is a parameter, characterizing the envelope and depending on moving coordinates [5].

Correlations

$$\varepsilon_{ij}=\lambda\frac{\partial\varphi}{\partial\sigma_{ij}}, \qquad (2)$$

where ε_{ij} - are the deformation components, σ_{ij} - are the stress components, $\varphi(\sigma_{ij})$ - is the condition of plasticity, in our case it has the form (I), λ - is the positive multiplier are used in the zone of non-elastic deformations. Besides (1) and (2) equilibrium equations, geometrical equations (equations linking displacements and deformations, and equations of non-separable deformation), which are true in the domain of elastic and zones of non-elastic deformations. The form of these equations is well-known and isn't given here. Hooke's law relations written in the corresponding system of coordinate are used along with enumerated equations for a link between stresses and deformations in the domain of elastic deformations.

Thus, the stress-deformed state round deep underground workings is defined by using of all enumerated correlations. So, in the case of deep extensive horizontal working this state is defined by the following components

$$\left.\begin{matrix}\sigma_{(\rho)}\\ \sigma_{(\theta)}\end{matrix}\right\}=\gamma h\mp\sin\varphi(\gamma h+\sigma_0/\alpha_2)(\rho_0/\rho)^2,\quad \tau_{(\rho\theta)}=0,$$

$$u_{(\rho)}=\rho\frac{\sin\varphi}{2G}(\gamma h+\sigma_0/\alpha_2)(\rho_0/\rho)^2,\quad u_{(\theta)}=0,$$

$$\sigma_{[\rho]}=(P+K\,ctg\varphi)\rho^{\alpha_2}-K\,ctg\varphi, \qquad (3)$$

$$\sigma_{[\theta]}=\alpha_1(P+K\,ctg\varphi)\rho^{\alpha_2}-K\,ctg\varphi,\quad \tau_{[\rho\theta]}=0,$$

$$u_{[\rho]}=\rho_0\frac{\sin\varphi}{2G}(\gamma h+\sigma_0/\alpha_2)(\rho_0/\rho)^{\alpha_1},\quad u_{[\theta]}=0,$$

where parentheses of the indexes mark the components relating to the domain of elastic deformations, and square brackets - mark the components relating to the domain of inelastic deformations, σ_ρ, σ_θ, $\tau_{\rho\theta}$ - are stress components, u_ρ, u_θ - are displacement components, $\alpha_1=(1+\sin\varphi)/(1-\sin\varphi)$, $\alpha_2=2\sin\varphi/(1-\sin\varphi)$, φ - is the angle of inner friction of the rock; K - is the linking coefficient of the rock in the zone of inelastic deformations, σ_0 - is the strength limit of the rock at uniaxial compression, G - is a shear modulus, ρ_0 - is the radius

of inelastic deformation zone. In this connection the relation which defines the character of interaction of rock mass with the horizontal working timbering is as follows:

$$u_{R_0}=R_0\frac{\sin\varphi}{2G}\left(\gamma h+\frac{\sigma_0}{\alpha_2}\right)\left[\frac{(1-\sin\varphi)(\gamma h-\sigma_0/2)+K\,ctg\varphi}{P+K\,ctg\varphi}\right]^{\frac{1}{\sin\varphi}} \qquad (4)$$

Relations similar to the expressions (3) and (4) are also received for the working of spherical form. So, the dependence similar to (4) used for deep spherical working is as follows:

$$u_{R_0}=R_0\frac{\alpha_2(\gamma h+\sigma_0/\alpha_2)}{2(1+2\alpha_1)G}\left[\frac{3\gamma h-2\sigma_0+(1+2\alpha_1)K\,ctg\varphi}{(1+2\alpha_1)(P+K\,ctg\varphi)}\right]^{\frac{2\alpha_1+1}{2\alpha_2}} \qquad (5)$$

According to the relations (4) and (5) static equilibrium in the system timbering-rock is kept at different P and every pressure value corresponds to a spherical radial displacement of working walls. In a general case the more displacement of the working contour the timbering allows, the less pressure it has. The statical pressure exists even at $P=0$, i.e. without timbering. The displacements of timbering contour points have final specific values.

However, analytical investigations (stage II) and observations in industrial conditions [1], show that at contact pressure when it is lower, than some critical P_* the process of the loss of rock equilibrium in near-contour zone.

In connection with this, the relations (4) and (5) define the character of rock mass interaction, surrounding the working, with the confirming construction up to the loss of their stable equilibrium.

The determination of P_* is of great practical interest, as P_* corresponds the least contact pressure on timbering, at which the stability of rock of near-contour zone is preserved.

According to stage II, the analysis of the stable state of the near-contour equilibrium zone on the basis of the deformed solid stability theory principles is carried out.

In addition, it's supposed that under the loss of stability of equilibrium state some perturbed state [denoted by the superscript "prime"] is imposed upon the stress-deformed state, which is defined by the components (3) [denoted by superscript "0"].

The solution of the problem is sought from:

$$\sigma_{ij}=\sigma_{ij}^0+\sigma_{ij}',\qquad u_K=u_K^0+u_K'. \qquad (6)$$

The components with the superscript "prime" are infinitesimal additional stresses and displacements of body points, turning the deformed initial state (3) into perturbed.

The solution of the problem is reduced to the determination of such meanings as $P=P_*$ and $u_{R_0}=u_*$ at which the perturbation components are different from zero.

Thus, as a result of such analysis the value of rock pressure on timbering P_* and the value of displacement u_*

of working contour,

We'll note, that under the examination of stability equilibrium construction the loading on it, usually, increases from a zero to its critical value. In the rock pressure problems the case is somewhat different. If we apply the pressure $P = \gamma h$ on the working contour, then the rock near it is always will be stable and that's why in such problems the pressure decreases from the value γh to its critical value P_*, and the radial displacement U increases from the zero to critical U_*.

Thus, the analytical notation of stable condition of equilibrium of the rock near working has the form:

$$P \geqslant P_*, \qquad U \leqslant U_*. \tag{7}$$

The values P_* and U_* depend from the mechanical characteristics of rock timbering, mechanical properties of rock surrounding the working, from the deepness and geometrical size of working. These data will be optimal at the timbering planning, as P_* - is the least pressure on the timbering, U_* - is the greatest admissible displacement, under which the stability of near-contour zone rock is provided. Obviously, that a timbering support with this parameters will be easier and has economical importance.

In view of the article boundedness I can give only final expressions P_* and U_* for deep level timberings and spherical timberings. Rock pressure on timbering and displacement of a working contour for a deep streched level working may be founded as

$$P_* = \frac{(1-\sin\varphi)(\gamma h - \sigma_0/2) - (\rho_*^{\alpha_2} - 1)K\operatorname{ctg}\varphi}{\rho_*^{\alpha_2}}, \tag{8}$$

$$U_* = R_0 \frac{\sin\varphi}{2G}(\gamma h + \sigma_0/\alpha_2)\rho_*^{\alpha_1+1}, \tag{9}$$

where ρ_* - is a non-measurement critical radius of non-elastic deformation zone, which is defined by the equation

$$\alpha_1\alpha_2 A\rho_*^{\alpha_2+2} - \alpha_1(1+\alpha_1)(A-B)\rho_*^{\alpha_2} - \left[\frac{(1+\alpha_1)^2}{2}B + (1+\alpha_1) - 2\alpha_1 A\right] = 0, \tag{10}$$

$$A = \frac{\gamma h + \sigma_0/\alpha_2}{2G}, \qquad B = \frac{(1-\sin\varphi)(\gamma h - \sigma_0/2) + K\operatorname{ctg}\varphi}{2G}.$$

Rock pressure on timbering contours and displacement value for a deep spherical working is determined by:

$$P_* = \frac{3\gamma h - 2\sigma_0 + (1+2\alpha_1)K\operatorname{ctg}\varphi}{(1+2\alpha_1)\rho_*^{2\alpha_2}} - K\operatorname{ctg}\varphi, \tag{11}$$

$$U_* = R_0 \frac{\alpha_2(\gamma h + \sigma_0/\alpha_2)}{2(1+2\alpha_1)G}\rho_*^{2\alpha_1+1}, \tag{12}$$

and ρ_* we find from the equation

$$\rho_*^{2\alpha_1+1} + C\rho_*^{2\alpha_1-1} + \left(\frac{2}{2\alpha_1-1} - D\right) = 0, \tag{13}$$

where

$$C = \frac{\alpha_2[3\gamma h - 2\sigma_0 + (2\alpha_1+1)K\operatorname{ctg}\varphi]}{(2\alpha_1-1)(\sigma_0+\alpha_2\gamma h)} - \frac{2\alpha_1+1}{2\alpha_1-1},$$

$$D = \frac{\alpha_2(1+\alpha_1)[3\gamma h - 2\sigma_0 + (2\alpha_1+1)K\operatorname{ctg}\varphi] + 3(4\alpha_1^2-1)G}{3\alpha_1(2\alpha_1-1)(\sigma_0+\alpha_2\gamma h)}.$$

The proposed method for optimal characteristic of the supporting constructions calculation granting takes into account the character of rock destruction, its physical-mechanical properties, its deepness and geometrical size of working. Due to the modern computers the solving of the equations (10) and (13) isn't so difficult.

The obtained meanings P_* and U_* are compared with the industrial observation data.

You can find a more detailed description of stress-deformed state and stability of equilibrium state of massive bodies with cavities, and of the elements of thick-walled constructions in respect to the problems of rock mechanics in monograph [1].

The methods of calculating parameters of an pliable supporting and those of monolithic and roof (anchor) supports and also cross dimensions of stable pillars and underground cavities to store oil and gas are also calculated by the suggested methods.

The methods are well illustrated with examples.

In this paper, a thorough enough review of such investigations is given and it's marked that similar investigations were conducted exclusively in the USSR.

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