MODEL OF DEFORMATION OF PILLARS WITH CONSIDERATION OF THE EFFECTS OF ENERGY STORAGE AND WEAKENING OF THE MATERIAL

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The problem of deformation of pillars is one of the urgent problems in mining. Interest in it is related, on one hand, to its applied significance and, on the other, to its theoretical significance, since the statement of the problem makes it possible in a number of cases to considerably simplify the configuration of the deformable region and boundary conditions (i.e., in essence, to reduce the problem to uniaxial compression). Because of this it is possible to examine more complex mechanical models.

It is known that the entire history of evolution and deformation of the rock mass is imprinted in the structure of solid useful resources and surrounding rocks, in the distribution of their jointing and micro- and macrostresses at various scale levels. The indicated conditions are distinguished by great diversity. Therefore, it is impossible, apparently, to find many universal solutions. More realistically we can undertake an investigation of a number of idealized situations with the use of various mathematical models of the rock mass.

The problem of a rock pillar was investigated in various formulations [1-3]. In most of them its solution was constructed on the basis of classical models of elasticity and plasticity. However, data have presently been accumulated showing that one of the main factors influencing the behavior of a rock mass is the capacity of rock to store elastic energy at microlevels of various scales.

Facts are known when the reaction of the rock mass to blasting is unusual. In certain cases the reaction of the rock mass to blasting can be observed for a long time after the explosion. Jolts, movements, and sometimes rockbursts are recorded in the mass [4]. This indicates that a redistribution and partial release of the energy stored in the rock mass earlier in the form of self-balanced stresses occur in it.

Laboratory experiments to determine creep of rock specimens extracted from great depths are known [5]. An anomalous behavior of the specimens during loading was sometimes observed in these experiments: instantaneous elastic shortening in the direction of the applied load. Here further development of creep not uniformly but intermittently occurred.

An experimental model of a rock specimen was proposed in [6] for illustrating the energy storage property. The specimens was a bundle of rough bars tightened by an elastic shell. A number of experimental results on uniaxial compression of such a specimen were given. It was shown that a considerable part (up to 30%) of the energy spent can be stored. References to the literature containing additional facts in this connection are also given.

The effect of energy storage at structural levels of the medium differs in its nature from the storage of the usual elastic potential energy in the rock mass. Any volume element of the rock mass is under the effect of gravitational and tectonic stresses and hence has a certain elastic potential energy of deformation. If this volume is withdrawn from the mass and is completely freed from all boundary stresses, it will be unloaded and the indicated energy will be released. Such energy can be referred to ordinary potential energy.

In the present work we will mean by stored energy (at the microlevel) only that part of the energy which is not released during the procedure indicated above. This energy is preserved at the microlevel and can manifest itself at the macrolevel. The process of its release under certain conditions has an uncontrollable dynamic character. It must be emphasized that it is impossible to take into account this energy source by classical equations of a continuous medium without consideration of the internal structure (microvariables).

References to the literature containing additional facts in this connection are also given.

Thus, the processes of storing energy in a rock mass play a considerable and sometimes determining role in its deformation. In connection with this, the problem of constructing appropriate mathematical models taking into account the effects of energy storage acquires urgency. Works [7, 8] were carried out in a similar direction for plastic media.

1. The concept of rock as a medium with internal energy sources and sinks was developed in [9]. It is based on ideas about rock as a medium having an internal structure. The structure is modeled by a relatively rigid skeleton representing a certain packing of particles and by cementing material which fills the pores between the particles. The appropriate fields of microvelocities and microstresses are introduced and the averaging operations making it possible to pass to macroparameters of the model are determined.

The model representations [9] describe a rather broad class of structural materials. By varying the properties of the structural elements (particles, porous medium, conditions at the contacts) one can construct models for rocks with different jointing, for loose media, and dry and saturated soils.

In the present work we will examine one of the possible variants of the model. Assume that the structural elements (particles and porous material) are elastic media but with different elasticity parameters. At the contacts between particles we assign a nonlinear plastic law of slipping, including a stage of weakening. In this case the equations will be essentially nonlinear. According to [9], the model for increments will have the form

$$\frac{\partial \sigma_{11}}{\partial x_1} + \frac{\partial \sigma_{12}}{\partial x_2} + \Delta X_1 = 0,$$

$$\frac{\partial \sigma_{12}}{\partial x_1} + \frac{\partial \sigma_{11}}{\partial x_2} + \Delta X_2 = 0$$

(1.1)

$$\Delta \varepsilon_{11} = \frac{\partial \Delta u_1}{\partial x_1}, \quad \Delta \varepsilon_{12} = \frac{\partial \Delta u_2}{\partial x_2},$$

$$\Delta \varepsilon_{12} = \frac{1}{2} \left( \frac{\partial \Delta u_1}{\partial x_2} + \frac{\partial \Delta u_2}{\partial x_1} \right),$$

$$\Delta \varepsilon'_{11} = \frac{1}{2\mu'} \Delta t'_{11} - \frac{\nu'}{2\mu'} \Delta t'_{22},$$

$$\Delta \varepsilon'_{22} = \frac{1}{2\mu'} \Delta t'_{22} - \frac{\nu'}{2\mu'} \Delta t'_{11},$$

$$\Delta \varepsilon'_{12} = \frac{1}{2\mu'} \Delta t'_{12},$$

(1.2)

(1.3)