GEOMECHANICS

CONTROL OF ARCH FORMATION IN THE ROOM-AND-PILLAR SYSTEM OF MINING.
PART I. STRESS-STRAIN STATE OF THE ROCK MASS

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This article examines the problem of mathematical describing the deformation of an ore deposit consisting of alternating strong and weak layers for a variant of the room-and-pillar system of mining. Equations are derived to determine the stress-strain state corresponding to the boundary conditions.

INTRODUCTION

In the last few decades, the methods of rock mechanics have made it possible to obtain new results which have important practical applications. One of the examples is the establishing a zonal disintegration of rocks around underground workings [1, 2]. Generalization of this phenomenon on the basis of the postulates of solid-state physics led to the discovery in [3]. The theoretical value of these studies lies in the establishment of the scientific foundation of nonlinear geomechanics [4]. As regards the practical side, the main benefit is determination of the feasibility of maintenance of underground workings at great depths, when the acting stresses from the weight of the overlying series reach the ultimate strength of the rock exposure. When disintegration occurs in the rock mass, the working is loaded by the part of the mass which is within the disintegration zone. Unfortunately, these findings were not included in the fundamental work [5], where the most important research trends in nearly all branches of the mining sciences are indicated.

Long and systematic researches [6-10] have shown that the formation of the arch above a working is a manifestation of the fact that a disintegration zone is located closer to the working than are other zones of arching. Below, we present a mechanical-mathematical formalization of such an approach for a layered series which is of variable strength and contains hard rocks including ore-bearing and weak enclosing rocks.

FORMULATION OF THE PROBLEM

Underground mineral deposits are commonly mined by systems that entail the use of an open goaf. In domestic and foreign practice, lodes which contain high-strength ores and relatively stable enclosing rocks are mined using a variant of the room-and-pillar system with wide barrier pillar leaving [11]. In terms of its technical-economic indices, this variant is inferior only to opencast mining and caving systems. The main problem that has to be solved in ensuring the stability of the mine goaf and efficient mining of the deposit, especially with an increase in depth, is control of the distribution of the loads between the barrier pillars and the interchamber pillars [12–15].
We studied the possibilities of unloading the pillars and attempted to determine the required parameters. The possibility of such unloading is related to the width of the barrier pillars, the height of the rooms, the number of rows of interchamber pillars in a panel, the elastic modulus of the material comprising those pillars, the depth of the lode, and the span of the mine goaf. Not enough attention has been given to developing analytical methods of solving the given problem. For example, in the Instructions for Mining of the Zhezkazgan Deposit [16–18], the unloading of the pillars is accounted for by the introduction of an empirical coefficient. The value of the coefficient depends on the ratio of the width of the lode to the depth of the working, the composition of the rocks of the roof floor, and the minimum dimension of the barrier pillars. These quantities are evaluated on the basis of data from instrument measurements in mines and centrifugal modeling in the laboratory. The studies conducted to date have not completely solved the problem.

There are methods which control the distribution of the loads between barrier and interchamber pillars by creating artificial compliance in the interchamber pillars within the range of feasible elastic strains of the roof rocks. However, these procedures are very complicated and have not been widely used in practice up to now.

We will examine the behavior of a rock mass above a mine goaf. The intact mass is in a state of equilibrium which is disturbed by the formation of the mine goaf. The equilibrium state must be reestablished by a corresponding redistribution of the loads among the pillars. The barrier pillars must carry the main part of the load from the overlying rock series, while the interchamber pillars need to carry load only from the weight of the rock directly under the arch. It follows from this all of the pillars will function as intended only if a state of natural equilibrium is established above the mine goaf. Only in that case the room-and-pillar system is the most efficient and safest mining system, particularly at deep levels. An arch natural corresponding to the equilibrium of rocks can be formed when the overlying series sag above the interchamber pillars, which in turn requires that those pillars be more compliant than the barrier pillars. The articles [8–10] and the present investigation are devoted to the solution of this problem.

The stress-strain state of the rock mass is formed depending on the degree of the overlying sagging above the interchamber pillars series and determines whether the mass is stable or unstable. Thus, the problem is to analytically describe the stresses, strains, and displacements of the overlying series in order to control the redistribution of the loads on the interchamber pillars within the range of elastic deflection of the roof of the mine goaf, with allowance for the mining-geological and physico-mechanical properties of the rock mass.

SELECTION OF CALCULATED SCHEME AND DETERMINING STRESS FUNCTIONS

The object of study here consists of ore deposits in which layers of strong rocks alternate with weak enclosing rocks. Lodes with such a geological structure are typical for the Zhezkazgan deposit, where benches of strong gray sandstone alternate with benches of weak red sandstone [19]. The gray sandstone are 30 or more times stronger than the red sandstone.

Figure 1 shows the geologic cross-section (M 1:2000) of the Zlatoust 2-IV lode in the Vostochno-Zhezkazgan Mine No. 57. The ore body consists of gray sandstone with polymetallic mineralization. The lode dips 3–5° from the north-east to the south-west and lies at a depth of 240–260 m.

To conduct analytical studies, we will make use of the following simplifications (Fig. 1). In accordance with standards [16–18] on substantiating the parameters of a room-and-pillar system, a lode is considered gently sloping if the dip angle is no more than 15°. In this connection, the boundaries of the benches of gray sandstones and the red rocks are represented in the form of horizontal straight lines. The thickness of individual benches which have constrictions is represented as an average. As can be seen, the idealized form of the geologic cross-section (Fig. 2) differs little from the actual form (Fig. 1).