IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Geomechanical assessment of processes for staged development and cross-section support setting in extended mine workings

To cite this article: VM Seryakov 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **262** 012066

Geomechanical assessment of processes for staged development and cross-section support setting in extended mine workings

VM Seryakov

Chinakal Institute of Mining, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

E-mail: vser@misd.ru

Abstract. The stress state of a rock mass and support members in the staged advance of two parallel workings is calculated. The feasibility is demonstrated to solve such problems by using the stiffness matrix of the calculation system which remains unchangeable in the development stages. Two versions of mining and construction processes are considered. Specific features of stress-field formation in the support system are discussed. The recommendations on selection of a mining system, best from the geomechanical viewpoint, are worked out and set worth.

1. Introduction

It is impossible to substantiate the applicability of most modern mining processes and respective technological parameters disregarding geomechanical state of a rock mass in mining operations [1]. Configuration of a worked-out space is continuously changing, support members and constructions regularly erected in mine workings carry a partial load arising with mining advance. The mining with consolidating stowing appears the most demonstrative process in this aspect [2]. At every mining stage the workings earlier worked-out are filled with a material which physical and mechanical properties differ from ones of the host rock mass. In this connection a representative description of stress and strain field redistribution in the vicinity of a worked-out space can be gained by considering all the mining stages. The theoretical approach to modeling of the stress-strain state of a rock mass considering a mining sequence stumbles across a number of mathematical and technical obstacles [3]. The researchers working for MI SB RAS developed the methods, applicable to settle all these challenges and to study redistribution of stresses in a rock mass in the course of stoping and stowing operations [4].

2. Different mining sequences and stress state features

In the present paper the novel methods are used for geomechanical studies of advance and support setting in two parallel tunnels. Figure 1 demonstrates one of mining and support setting processes applicable to drive two parallel tunnels [5]. At every mining stage a fresh-driven section of a tunnel is reinforced with temporary or compressible support. The support system and surrounding rocks form a construction apt to deformation when initial stresses release in surrounding rocks. The permanent support is set after the release of initial stresses acting in a rock mass is actually realized, so permanent supports experience insufficient portion of acting load in fact. Actual strain and loading of supports is mainly observed as a consequence of further driving of parallel tunnels. Therefore, the stress field in support members and a surrounding rock mass can be calculated by using a software system designed to compute a stress-strain state of "supports–host rock mass" with account for a mining sequence practiced in this very case [1, 4].

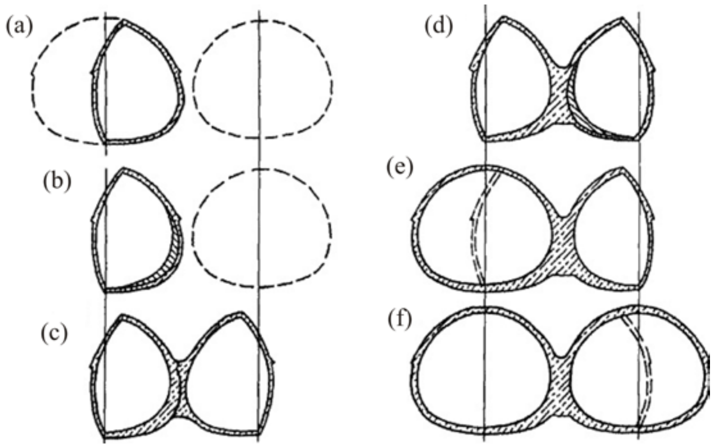

Figure 1. Staged opening of cross-sections of parallel tunnels [5]: a—opening of the right adit in the left tunnel with a temporary apron made of reinforced shotcreting; b—multilayed shotcreting on the right side of the adit; c—opening the left adit of the right tunnel and erection of a temporary apron made of reinforced shotcreting; d— multilayed shotcreting on the left side of the adit; e—complete opening of cross-sections of the left and right tunnels.

The idealized version of the mining sequence under consideration is shown in Figure 2a. Another possible version of a mining sequence and reinforcing of parallel tunnels is demonstrated in Figure 2b. It is impossible to justify a rational mining sequence disregarding regularities in redistribution of stress fields in a host rock mass and support members.

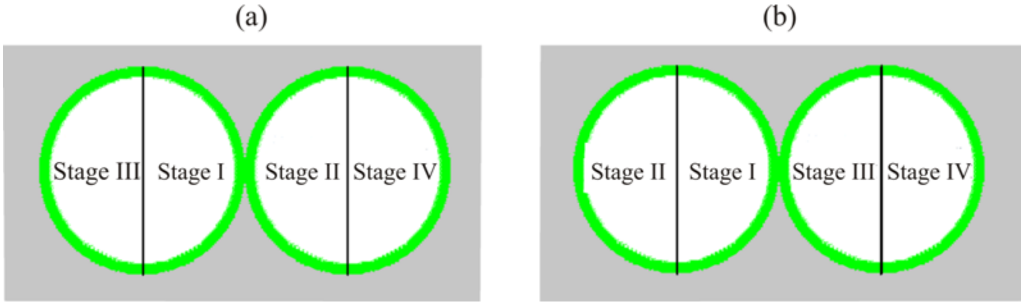

Figure 2. Versions of mining sequence to drive and to reinforce parallel tunnels: a—the first variant; b—the second variant.

Specific features of stress-field formation in supports and surrounding rock mass were earlier considered for the second mining variant [6]. According to the basic calculation conclusions the application of the calculation method for computing a stress-strain state of a rock mass with account for the mining sequence to solve the problem of opening cross-sections of parallel mine workings enables to establish specific features of the formation of concentrated tension and compression stress zones in support members and to identify mining stages where they reach the maximum. To the point, the most failure-hazardous situation in the support system is resulted from the third-stage operations on opening cross-sections of parallel tunnels.

Let compare stress fields, formed in a rock mass and support members in similar stages of the tunneling variants under consideration. Like in [6] we assume that the length of mine workings is significant, ant the plane strain terms can be accepted. Boundary conditions on outer contours of the calculation domain are suggested as follows: zero values of the horizontal component of displacement vector *u* and tangential component of stress tensor τ_{xy}. These terms correspond to the initial stress state of a rock mass with stress tensors: $\sigma_y^0 = \wp H$; $\sigma_x^0 = \nu \wp H / (1-\nu)$; $\tau_{xy}^0 = 0$, known as "gravity" initial stress field. Here σ_x^0, σ_y^0, τ_{xy}^0 are normal and tangential components of stress tensor; $\wp$ is volumetric rock weight; *H* is distance from the daylight surface to the top boundary of mine workings. Axis *Ox* is horizontal and *Oy* is vertical.

The upper horizontal boundary of the calculation domain is free of external load action. The zero vertical component of displacement vector *v* and tangential component of stress tensor τ_{xy} are suggested on the horizontal bottom boundary. The calculations are made at the following mechanical properties: Young's modulus *E*= 25000 MPa; *ν* = 0.25 for host rocks and *E* = 50000 MPa, *ν* = 0.2 for the support system. Volumetric rock weight is assumed equal to 0.03 MN/m^3.

The analysis of calculation results by using the final element method [7, 8] for the stress state of a rock mass and support members in the second mining variant made it possible to establish that the maximum concentration of compression stresses in both supports and rocks is reached in the area of connection of parallel workings. In view of the above, let consider variations in the stress state in details in this very area in the course of mining operations. The distribution isolines of the second principal stress after the third mining stage in the mining variants under consideration are shown in Fig. 3.

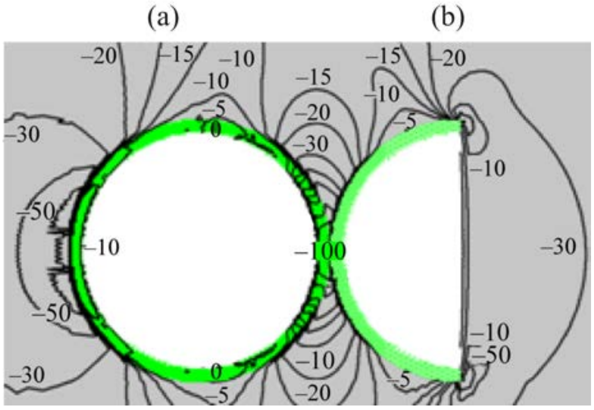

Figure 3. Distribution of the principal stress σ_2 in supports and a rock mass in the third stage of cross-section opening of two parallel workings in the first and second mining sequence variants.

In the first mining sequence variant the compressive stresses σ_2 in the support system are lower than those in the second variant, perhaps, due to the fact that in the first variant the weight of the rock, occurring above development workings (bearing pressure), is taken up with support members erected in both first and second workings under development. In the second mining variant the bearing pressure in the point of connection of workings is taken up by support members erected only in one working.

The final pattern of distribution of the principal compressive stress σ_2 at the point of parallel workings conjugation after fulfillment of all the mining stages is presented in Figure 4. It is obvious that at conjugation point the compression level in the supports is higher in the second variant and exceeds 100 MPa by absolute value.

The analysis of the character of stress redistribution in support members in mining with opening of cross-sections of parallel workings enables to establish some more specific features of their stress state. Thus, stepwise erection of support members in the development workings induce formation of tensile stress areas. Location of such areas and tension level in them vary in the course of mining operations, moreover, the highest stress values are gained at intermediate mining stages. The final distribution picture of the first principal stress, which enables to establish zones of tensile stress formation, reveals a tension level much lower as compared to tension levels at preceding tunneling stages. All the above confirms the must to consider the stress-strain state of the support system and a surrounding rock mass in the staged driving and support setting in mine workings.

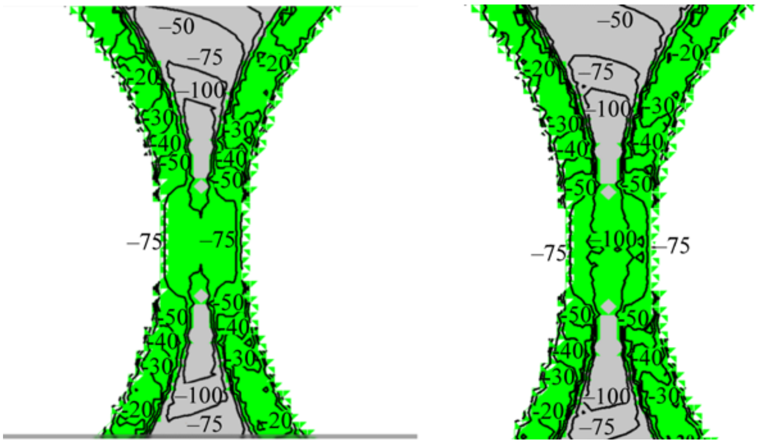

Figure 4. Distribution pattern of stress σ_2 in conjugation area for two parallel workings in the final stage of the first and second tunneling variants.

3. Conclusions

1. Calculation of a stress-strain state of a rock mass and support members in compliance with conditions of the staged advance and support setting in two parallel workings makes it possible to establish specific features of formation of tensile and compressive stresses in support members and to identify actual mining stages at which they reach the highest values.
2. It is established that the stepwise erection of support members in development workings induce formation of tensile stress zones, the maximum stress values are gained at intermediate stages intended to open cross-sections of parallel mine workings.
3. Geomechanically, the most acceptable mining variant to open and to reinforce cross-sections of parallel workings is a mining sequence where formation and reinforcement of sections of parallel workings are provided in areas of their conjugation at first stages.

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