LOCATION OF UNDERGROUND MINING WORKS SITUATED NEAR AREAS WITH MAJOR TECTONIC ACCIDENTS

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Abstract *The paper presents a method for determining the minimum safety distance of underground workings from areas with major tectonic accidents (block faults). Of course, the proposed method was applied for a case study (a concrete situation encountered in one of the underground mining operations in the Jiu Valley), and for its validation other determinations must be made, for other similar situations.*

Keywords: *tectonic accidents, mining support establishment, safety pillar*

1. Introduction

The sedimentary of the Jiu Valley mining basin is a rock stratification massif; it is a succession of extremely diversified layers, of variable thicknesses, which gives it a dense sediment structure. Based on the fact that it can be ascertained, it can be stated from a geo-mechanical point of view, the rock massif is of discontinuous heterogeneity.

The tectonic evolution of the depression in Petroșani is a development as it recedes, given that it exists in certain parts and in other parts of the basin. The litho-facial evolution of the basin sedimentary is diversified; this occurred in the eastern area for a longer period than in the western area.

The phenomena and actions of tectonic nature with general orientation northwest-west-south is a product in time or a series of cracks and fractures, the care gives the mining basin Jiu Valley appearance with graben.

The main categories of rocks related to the Jiu Valley coal basin are sandstones, clays, marls, marl-limestone, micro-conglomerates, with their varieties. From the geological mapping carried out so far, it was found that, starting from the bed of layer 3, the types of intercepted rocks are, in order: sandstones, clays, marls or coal.

2. Theoretical considerations

In the coal mines of the Jiu Valley the assessment of the stability of mining works located near tectonic disturbances is based on the experience gained over time by mining in this basin in conjunction with systematic research on the geological, hydrogeological, mechanical and rheological characteristics of rocks and coal (pit coal) which make up the analyzed area.

Knowledge of these characteristics is a sine qua non condition for the location of mining works (eg. inclined planes of attack) near major tectonic disturbances (block faults) because heterogeneity, anisotropy, heterotopy and non-elastic behavior of the massif are the consequences of macro and microscopic fragmentation, with special influence on these mining works related to the technological process of coal extraction.

Therefore, the elaboration of the framework methods for the exploitation of coal seams, but especially of the thick ones, extracted by the method with undermined coal bank, must be the exact knowledge of the areas with tectonic accidents of the massif [3].

The analysis of the stability of the mining works (inclined attack planes) executed near the areas with tectonic accidents must take into account both the parameters that characterize the natural conditions (depth of exploitation, the nature of the rocks in the fault and the roof of the layer) and those specific to exploitation conditions (shape and size of the work profile, execution technology).

The depth of location of mining works (plans, attack galleries) is one of the most important technical-mining factors in ensuring their stability. As the depth increases, there is practically a change in the geo-mechanical properties of the surrounding rocks, a transition of them to a limit state that influences the stability of the work. The natural and secondary state of tension is amplified [3].

3. Determining the stability of mining works located in areas with tectonic accidents

One of the procedures to ensure the stability of inclined planes (galleries) of attack located in areas with tectonic accidents is to leave some safety pillars.

To determine their size, the block fault was assimilated with a slope.

In order to verify the stability of the slope, in addition to knowing its geometric elements, it is necessary to choose the calculation values for the geotechnical characteristics of the component rocks [2, 5].

In the following, knowing the stratigraphic columns based on research drilling, the existing mapping at mining operations, as well as geo-mechanical studies, conducted over time by

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specialists in the field, will present an example of calculating the stability of a step that it has in its composition a thick layer of coal and the rocks from its direct roof, a step whose slope is assimilated to a fault.

The calculation data are as follows:

- the apparent (volumetric) weight of the coal in the step composition: γ_{ac} = 13 kN/m^3;
- apparent (volumetric) weight of the rocks in the direct roof: γ_{as} = 26 kN/m^3;
- coal cohesion: c_c = 1500 kN/m^2;
- cohesion of waste rocks: c_s = 6000 kN/m^2;
- the internal friction angle of the coal: $\varphi_c = 40^0$;
- the internal friction angle of waste rocks: $\varphi_s = 50^0$;
- angle of inclination of the fault (slope of the step): $\beta = 60^0$ or slope 1: m = 1: 0.58;
- inclination of the coal seam and the direct roof: $\alpha = 45^0$;
- thickness of the coal layer: g = 25 m;
- thickness of rocks from the direct roof: g_1 = 12 m;
- step height: $H = \dfrac{(g+g_1)\cdot \sin 60^0}{\cos(60^0-45^0)}$ = 33 m;
- the stress at the upper part of the analysed fault area: p = 2000 kN/m;
- stress on the fault (slope): p = 2000 kN/m.

For the stability analyses of the slope, a specialized software in geo-technics was used. This is a 2D software that analyzes the stability of natural and artificial slopes, with complex geometry, composed of homogeneous or heterogeneous rocks, developed by Rocscience. It is designed to assess the safety factor or the probability of failure, for circular or non-circular surfaces, for weakly cohesive or cohesive materials [6]. Although it is a very simple software to use, the program can create and analyze complex models, under normal static conditions or taking into account seismic shocks, overloads, the influence of groundwater, cracks due to tension or various structures to increase the stability reserve (retaining walls, anchors etc.)

Slide analyses the stability by the method of vertical stripes at the equilibrium limit. Individual surfaces can be analyzed or methods for determining critical slip surfaces for a given slope can be applied.

The first step in using the software is to model the slope and introduce the physical and geo-mechanical characteristics of the rocks (volumetric weight, cohesion and internal friction angle).

The next step is to define the sliding surface or grid that contains possible sliding surfaces. The program automatically calculates the stability coefficients, using for this purpose several methods (Fellenius, Janbu, Bishop, Spencer, Morgenstern-Price etc.). Finally, the critical slip area is determined, which corresponds to the minimum value of the stability coefficient [1].

Only the Fellenius method was used for this study, as this method (confirmed by countless previous studies) leads to the lowest values of the stability coefficient. The method assumes that the sliding surface follows a cylindrical-circular (curved) pattern. The stability of the slope is analyzed in the hypothesis of the boundary equilibrium between the active and passive forces acting on the sliding prism [1, 4]. To calculate the value of the stability coefficient, the sliding prism is divided into several vertical strips. The forces acting on each strip (in the absence of seismic shocks) are highlighted in fig. no. 1.

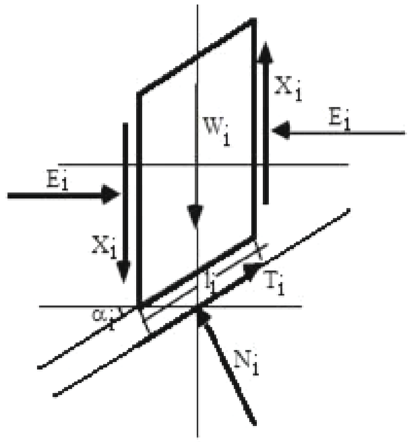

Fig. 1. *Forces acting on a strip [1]*

Notations in the figure: Wi – strip's weight; Ni – normal component of the force of gravity; Ti – tangential component of the force of gravity; Ei – horizontal forces transmitted to neighboring strips; Xi – vertical forces between neighboring strips; αi – inclination of the strip (to the horizontal); li – width of the strip;

The numerical solution of the stability coefficient was obtained assuming that the horizontal and vertical forces that occur along the strips (Ei, Xi) are equal to zero. Starting from the equilibrium condition, the stability coefficient Fs of a slope is calculated by the formula [1]:

$$Fs = \frac{tg\varphi \sum_1^n W_i \cdot \cos\alpha_i + \sum_1^n c \cdot l_i}{\sum_1^n \pm W_i \cdot \sin\alpha_i}$$

where: c – rock's cohesion along the strip;
φ – angle of internal friction along the strip;
n – number of considered strips.

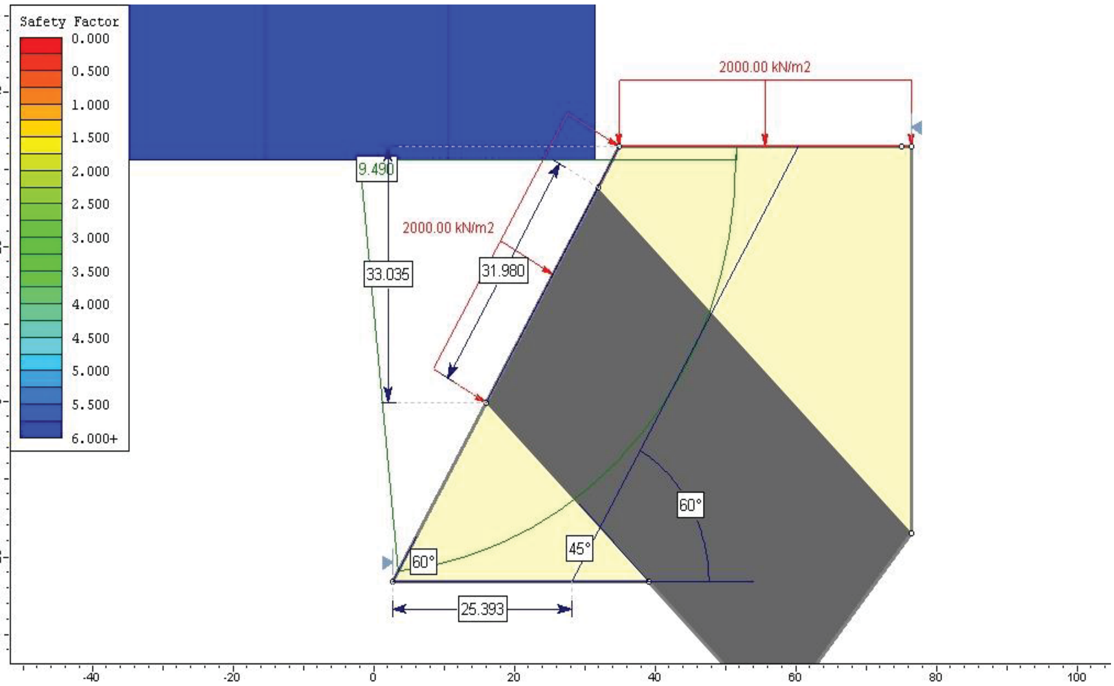

Fig. 2. *Determining the minimum stability coefficient and the critical sliding surface*

In the analyzed model, the overloads given by the weight of the rocks acting on the upper berm and on the slope p = 2000 kN/m were also taken into account (fig. no. 2).

After running the calculation algorithm, the solution, from fig. no. 2 (potential sliding surface, corresponding to the lowest value of the stability factor), is obtained. From this figure, it can be observed that the farthest point of the critical sliding surface to the slope, and so to the fault, is at 25.393 m.

4. Conclusions and suggestions

The proposed method for determining the minimum distance for the location of underground mining works from areas with major tectonic accidents is a simple one, which can be applied to other concrete situations encountered in practice.

The minimum distance of underground mining works from areas with major tectonic accidents is similar to that determined by other procedures and methods, but which involves a much larger volume of calculation and complex modeling.

Following the results of the above calculations, for this case study, it is proposed that the location of the inclined planes (galleries) of attack of the abattoirs be made at a minimum safety distance of 25.5 m from the areas with major tectonic accidents (block faults).

Also, if the advance direction of the working front is towards the fault, the exploitation will be stopped at a distance of at least 25.5 m from it.

This minimum safety distance is variable, specific for each situation analyzed, as it depends both on the characteristic geometric elements (slope inclination, coal layer inclination, its thickness, etc.) and on the physical and geo-mechanical characteristics of coal and rocks in direct roof.

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