RISK FACTORS FOR THE UNDERMINED COAL BENCH MINING

FACTORI DE RISC PENTRU EXPLOATAREA MINIERĂ PE BANC DE CĂRBUNE SUBMINAT

Victor ARAD[1], Susana ARAD[2], Nicolae ILIAŞ[3], Marian TICU, Liviu POPA[4], Ioel VEREŞ[5]

Abstract: *Coal seam exploitation in Jiu Valley coal basin is achieved in a percentage of 75% by employing the undermined coal bench mining method. The coal output obtained by this method is of about 3 million tons/year. The productivity obtained with this method is higher than 8 tons / shift. The values of these indicators, strongly recommends this mining method, for general use in the specific conditions met in Jiu Valley coal basin. However, over a time series of technical accidents such as explosions and ignitions of methane gas, roof blowing phenomena or self-ignition of coal and spontaneous combustions have occurred. In this respect, the paper tried to analyze the risk factors related to this mining method application.*

Keywords: Risk factors, geomechanical characteristics of rocks and coal, geodynamic phenomenon, spontaneous combustion phenomenon, gas accumulation.

Rezumat: *Exploatarea stratului de cărbune în bazinul de cărbune din Valea Jiului se realizează în procent de 75% prin folosirea metodei de exploatare a cărbunelui subminat. Producția de cărbune obținută prin această metodă este de aproximativ 3 milioane de tone/an. Productivitatea obtinuta cu aceasta metoda este mai mare de 8 tone/tur. Valorile acestor indicatori, recomandă cu tărie această metodă de exploatare, pentru utilizare generală în condițiile specifice întâlnite în bazinul carbonifer Văii Jiului. Cu toate acestea, de-a lungul unei serii cronologice de accidente tehnice, cum ar fi explozii și aprinderi de gaz metan, fenomene de suflare a acoperișului sau autoaprinderea cărbunelui și arderi spontane au avut loc. În acest sens, lucrarea a încercat să analizeze factorii de risc aferenti aplicării acestei metode miniere.*

[1] Professor in Rock Mechanics, Ph.D in Mining Engineering, Faculty of Mines, University of Petrosani, inginerie_miniera@yahoo.com

[2] University of Petroșani.

[3] Professor, University of Petrosani, Romania, e-mail: iliasnic@yahoo.com

[4] University of Petroșani.

[5] Technical University of Cluj-Napoca.

Cuvinte cheie: Factori de risc, caracteristici geotehnice ale rocilor și cărbunelui, fenomene geodinamice, fenomen de ardere spontană, acumulare de gaze

1. Risk factors

The main risk factors generating technical accidents are the geomechanical characteristics of coal and surrounding rocks, the dynamic phenomena occurring in the rocks within the coal seam's roof, accumulation of toxic and explosive gases in the gaps resulting from the exploitation, the mining method-s geometrical elements, the coal's proneness to spontaneous combustion.

1.1. Geomechanical characteristics of rocks and coal

The main geomechanical characteristics having implications in producing geodinamical phenomena were determined.

The measured parameters were: the cleave coefficient of structural weakening, specific density and volume, porosity, permeability, compressive strength and traction, the coefficient of strength, cohesion and internal friction angle, elastic and rheological characteristics of coal and surrounding rocks.

In view of assessing the main characteristics of the coal and rocks from the 3-rd seam coal samples have been collected from the several mine working faces of Petrila and from the direct roof and main roof. After the laboratory tests, the following results, listed in table 1, have been obtained.

2. Geodynamic phenomenon

The geodynamic phenomenon from face 431 had occurred due to the instantaneous decline of rocks within the main roof. Because of the piston effect, explosive gases within the gap developed in the third round, were pushed to the working face and on their route they met with the endogenous fire from slice IV, generating an explosion which resulted in 13 deaths and 18 injured workers (see figure 2).

2.1. The spontaneous combustion phenomenon

As a consequence of coal oxidation and self heating of coal mass left in the goaf spontaneous combustions can occur. . The oxidation mechanism is based on the theory of chain reactions, by which absorbed oxygen generates metastable compounds that dissociate easily, giving birth to phenolic groups, carboxylic or carbonyl and releasing the small quantities of heat.

The phenomenon of self-ignition includes 6 stages:

– Incubation phase

– Two stages of evaporation

– Two transition phases

– The combustion phase.

The main factors which are inducing coal self-ignition and combustion are:

– Physico-chemical composition;

– Moisture content, volatile material content, porosity, and specific surface;

– Petrographic composition

– Geological characterization: tilt and layer thickness, deposit's tectonics, gas content of coal layers

– Losses in the coal mined out;

– Inadequate ventilation system operation.

At the level of the 431 working face, the following spontaneous combustion occurrences took place:

– III subfloor, level - 222.3 13 February 2005

– II subfloor, level - 231.7 1 September 2006

– II subfloor, level - 200 1 October 2007

– III subfloor, level - 200 16 November 2007

Spontaneous combustions have occurred were basically generated by coal mass left in the goaf, low face advancing rates and also due to significant air losses within the retreating goaf.

The release of coal bed methane gas is an extremely complex phenomenon, that depends on many geomechanical and technical factors and parameters. The amount of methane released from working faces and preparation of working front is due to uncovering new areas, operations and cutting cleaves layers of coal mining under the pressure. A certain proportion of the free methane was evacuated in the return polluted air stream, and another part has been accumulated in the gaps of the exploited seam. Concentrations of methane in the transport and ventilation galleries ranged between 1.68% and 3.46% in the weeks before the explosion.

Ventilation activation, employed in order to reduce the concentration, led to increased losses of air through the use of fire and endogenous fire reactivation. In the gaps resulting from the mining operation, having a volume of 175,000 m3, methane has accumulated in explosive concentrations.

When rocks from the main roof were suddenly undermined, gas has been pushed to the endogenous fire zone.

3. The pressure and the height of the undermined coal bench geomechanically considered

For the exploitation with undermined bench method, we suggest a calculation hypothesis for the pressure according to which the pressure that actuate upon the working front is considered to be given by the weight of the smashed rocks which are to be found above the undermined bench, to that is added the bed's own weight, bed that gets broke on the (x) breadth which is the equivalent of the undermined pitch.(see figure no.3).

4. Equations

The force that oppose to the stress, is given by the cohesion and possibly by the friction force that actuates according to the shearing plan on the height (h).

Therefore, it can be written:

$$p = p'_1 + p''_1 \tag{1}$$

where:

p – the pressure that actuates upon the working front

p'_1 – the pressure created by the smashed rocks above the undermined bank and wich according to the hypothesis of the powder medium has the value:

$$p'_1 = p_1 \cdot i \cdot e^{-\Pi tg\varphi} \quad \text{[MPa]} \tag{2}$$

in which:

$$p_1 = 1,784 \cdot \gamma_a \cdot H \cdot x \quad \text{[MPa]} \tag{3}$$

φ – the friction angle of the smashed rocks;

x – undermined pitch

p''_1 – the pressure created by the undermined bank which is given by the undermined bed weight, less the shearing force that actuates upon the undermined bed height or:

$$p''_1 = Q - \tau_f \tag{4}$$

where: Q – the weight of the coal in the undermined bank:

$$Q = x.h.\, \gamma'_a \quad [\text{MPa m}] \tag{5}$$

γ'_a – the apparent specific weight of the coal;

$$\tau_f = C + \sigma_x \,\text{tg}\varphi \quad [\text{MPa.m}] \tag{6}$$

If neglecting the lateral pressure then*:*

$$\tau_f = C \quad [\text{MPa.m}] \tag{7}$$

On the height (*h*)*:*

$$\tau_{fh} = C.h \quad [\text{MPa.m}] \tag{8}$$

Considering a coefficient of structural weakening (C_s):

$$\tau\text{fh} = C.Cs.h \tag{9}$$

We obtain:

$$P = x.1{,}784\,\gamma a.H\,I.e{-}\pi\text{tg}\varphi + h\,(x.\gamma' a - C.Cs) \tag{10}$$

The limit height of the undermined bench is obtained from the following condition:

$$\text{p}' + \text{Q} = \tau\text{fh} \tag{11}$$

Substituting:

$$h = x.1{,}784.\gamma a\; H\,.i.\cdot e{-}\pi tg\varphi \qquad [\text{ m }]. \tag{12}$$

$$C.Cs - x.\gamma' a \tag{13}$$

If the result is divided by (*x*), we obtain the value of pressure in [MPa]. In this case, we have:

$$p''_1 = x.h.\,\gamma'_a - h.C.C_s = h\,(x.\,\gamma'_a - C.C_s) \quad [\text{MPa}\cdot\text{m}]$$

Wherefrom, it results: (14)

$$P = x.\,1{,}784\,\gamma_{a.H\,I.\,e}{}^{-\pi\text{tg}\varphi} + h\,(x.\,\gamma'_a - C.C_s) \quad [\text{MPa}\cdot\text{m}] \tag{15}$$

From the pressure relation structure and implicitly to the height of the undermined bank, we observe that among the parameters that influence these values the depth of the working front towards the (H) surface; the coal cohesion (*C*); the inner friction angle of the smashed rocks, φ ; the structural weakening coefficient, C_s, stand out.

5. Tables

Table 1. **Average values of the physical, mechanical, and elastic characteristics of 3-rd coal seam and rocks within the roof**

Name	Coal	Direct roof rocks	Main roof rocks
Specific weight, *g*, 10^4 N/m^3	1,45	2,65	2,67
Apparent specific weight, γ_a, 104 N/m3	1,31	2,58	2,6
Porosity, *n* %	9,7	3,5	2,6
Pares number, *e*	0,107	0,02	0,025
The breaking strength to compression σ_{rc} MPa	9,5	44,1	128
The breaking strength to dries σ_{rt} MPa	0,8-1,3	5,6	13,2
Cohesion *C*, Mpa	1,1-2,5	6	20,5
Inner abrasion angle φ ^{o}	49-58	50	54
Elasticity modulus, *E*, MPa	5300	8500	10500
The coefficient of Poisson, μ	0,17	0,2	0,12
Energetic, coefficient, I_e	-	1,32	2,2-3,7
The structural weakening coefficient, C_s	0,1	-	-

6. Figures

Based on the data synthesized in table1 the pressure and the height of the undermined bench have been calculated for the depths of Petrila working faces. They are plotted in the diagram represented in figure1.

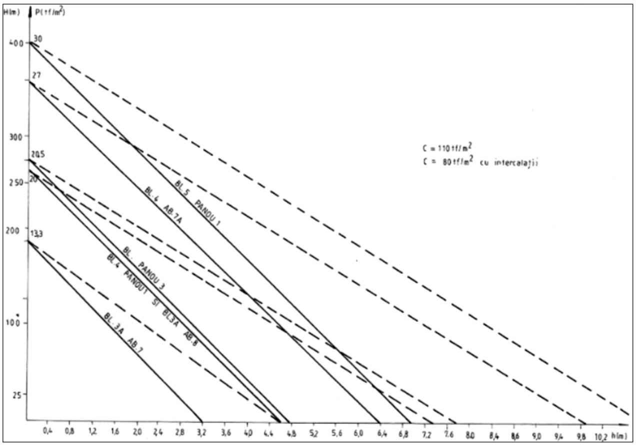

Fig. 1. The correlation between the depth (*H*), pressure size and height of the undermined bench, (*P*).

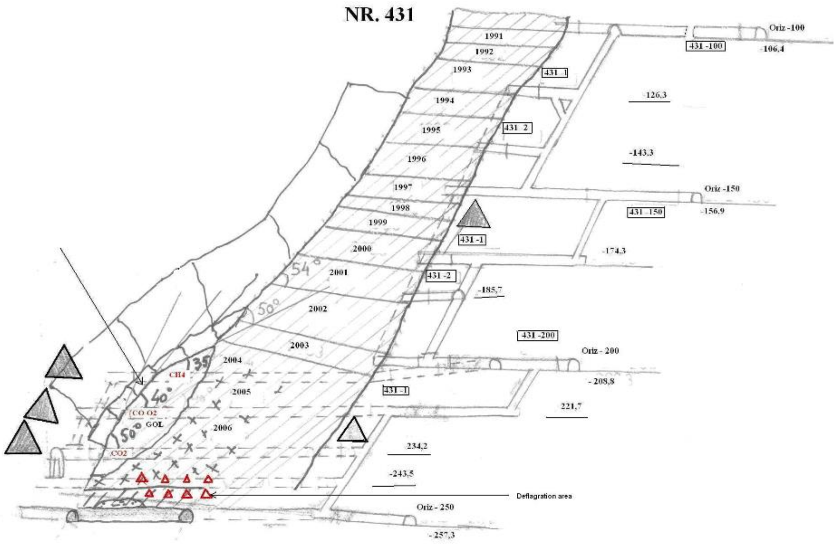

Fig. 2. The geodynamic phenomenon.

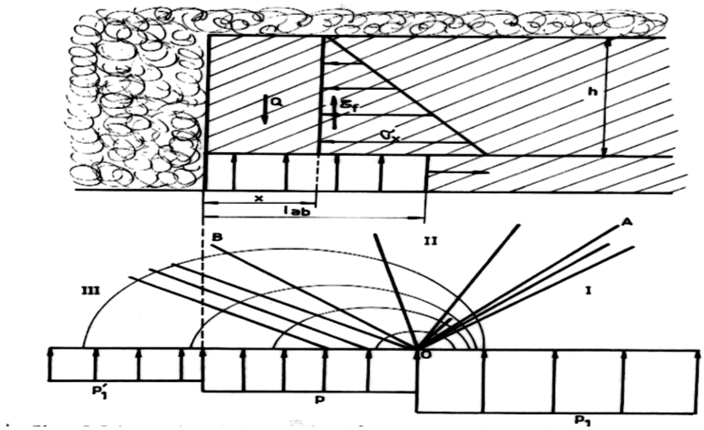

Fig. 3. The pressure calculation scheme for the undermined bank exploitation methods.

7. Conclusions

For the specific conditions encountered in Petrila colliery, the undermined banks height should be comprised between 5 and 7 m, depending on the geomechanical characteristics of coal and surrounding rocks.

The rocks within the main roof are having high values of the mechanical strength and energetical index, being characterized by a significant degree of proneness to dynamic phenomena. These kind of rocks are difficult to cave in, that is a major reason in resorting to controlled under-caving techniques.

The hard coal from seam no. 3 in Petrila colliery are having a pronounced tendency for self-ignition and spontaneous combustion, fact which is confirmed by several self-heating and endogenous mine fire episodes occurred already in this seam's area.

The hard coal mined at Petrila mine also has a high methane content, so values exceeding 15 m^3/ ton were usually met and measured.

Conclusively, we can state that the conditions from the working face AB 431, Petrila colliery all the risk factors were gathered, developing consequently a dynamic phenomenon and an explosion in the goaf.

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