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Choice of powered roof support FAZOS-15/31-POz for Vang Danh hard coal mine

Krzysztof Skrzypkowski[1)], Waldemar Korzeniowski[1)], Trung Nguyen Duc[1)]

[1)] AGH University of Science and Technology, Faculty of Mining and Geoengineering, Krakow, Poland

[2)] Institute of Mining Science and Technology, Hanoi, Vietnam, (PhD student at AGH)

Abstract. The article presents the choice of a Polish powered roof support from FAMUR Group for the conditions of one of the hard coal mines in Vietnam. In the analytical calculations, the strength and structural parameters of the rock mass from the Vang Danh mine region were adopted. The longwall face is 93 m long and the thickness of the coal layer is equal 3 m. For the needs of the choice of support, the load of the longwall face determined and the capacity of the powered roof support were determined. On the basis of the permissible roof deflection method, the condition of excavation maintenance was characterized. In the calculations, it was assumed that the condition of using a powered roof support type FAZOS-15/31-POz, except in addition to complying of the working range and permissible value of longwall face inclination, is to ensure proper roof maintenance conditions, which are determined by the index of load capacity of the roof „g".

1 Introduction

The main task of the support is to protect the working space in the operating front. By supporting the working space it is understood to prevent the fall of roof rocks into the excavation face and take over a dynamic loads. In order to fulfilled the tasks of support , it is necessary to check the possibility of using a given type of support in specific geological and mining conditions [5]. Due to the possibility of using the knowledge of support loads to better understand the phenomena occurring around it, programs recording the work parameters of complete longwall mining systems were created [3,7]. In an underground hard coal mines mining complex consists of shearer loader, armoured face conveyor and powered rood support that determines the safety and efficiency level of the mining process [17]. One of the decisive factors affecting on the correct choice of powered support is the cooperation between the base of the support and the floor of longwall face [6]. For longwall panel with caving, the roof rocks fall by gravity causing the filling of post-mining area. In underground excavations the compressibility of filling materials play a special role preventing, e.g. decreasing the surface and allow to manage the waste [13,14,19]. Very often mining supports cooperate with different types of reinforcement. In terms of rock mass prones to tremors, mining support should be adopted to energy – absorbing [11,12]. Correct selection of the load-bearing capacity of the supporting section to the size of the loads from the rock mass is not a guarantee of ensuring the stability of the longwall face. This is due to the fact that the possibility of creating in the longwall face with the maintenance of the roof, very often decides other reasons, for example, irregularities in the construction of the powered roof support or to use them [8]. The main factors affecting the choice of mechanized support were presented in the table 1. The general criterion on the basis of which the most often selected is the powered roof support in the mine is the compliance of the scope of its operation with the planned exploitation height [18]. Lack of detailed calculations of the load of the support and its capacity, as well as resistance to dynamic loads, may lead to a series of undesired events, for example the fall of roof rocks, clamping the support or its damage [15]. The phenomenon of loading a mining support with the weight of rocks may occur in the case of roofs with very low strength or in which there are completely damaged rocks. The behavior of the excavation support at such a load depends on the weight value of rock masses. The static load value lower than the load capacity (load capacity) does not cause dynamic phenomena. Only exceeding the operating values leads to clamping the support, which results from the operation of the protections. In a mechanized support, this is to open the outflow from the under-piston space of the stands through a working or pressure valve and to clamp the sections. If the load remains above the working load, the support is completely closed with all overloading consequences. In order not to allow such

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[1] Corresponding author: skrzypko@agh.edu.pl

a situation, it should be paid special attention to the selection of support and methods of protection. The mentioned two cases of behavior of a longwall face support can be presented by the relation [16]:

$$Q_i \cdot b < F_{zr} \rightarrow V = 0 \quad (1)$$
$$Q_i \cdot b > F_{zr} \rightarrow V > 0 \quad (2)$$

where:
Q_i – static load of a longwall face, $[N \cdot m^{-1}]$,
b – Centre sparing of powered roof support, [m],
F_{zr} – roof support capacity, [N],
V – velocity camping of powered roof support, $[m \cdot s^{-1}]$.

Table 1. Factors affecting on the choice of powered roof support

Geological	Production	Equipment
Coal seam thickness (thinning and thickening) and inclination	Length of face	Minimum and maximum working height of powered roof support
Faults (throw and inclination angle)	Length along the strike	Canopy load distribution
Depth of exploitation	Reserve of coal	Support yield ratio over the lift of the panel and set to yield ratio
In situ stress	Extraction height	Harmony between powered roof support and armoured face conveyor
Natural hazards (mainly: water, tremors)	Upper and lower mineable seams	Overall dimensions of support in transport position
Caving behaviour	Rate of face advance and production capacity	Mass of powered roof support
Strengh, deformation and structural properties of coal seam and surrounding rocks	Ratio of face to top coal	Possibility of remote control and monitoring

2 Stages of rock mass behavior loading in the longwall face

The relaxed rock mass can be divided into two parts (Fig. 1). The lower part is the immediate roof, which forms the most cracked layers and creates a chaotic rubble rocks in the goaf. The upper part is formed by the main roof, consisting of strongly fractured rocks, they retain the form of geometrical continuity in the goaf [16]. In the overlying rock layers above the relaxed rock mass, which can be described as a disturbed rock mass, as a result of the deflection of the layers during coal seam mining, cracks are also formed. The frequency of these cracks is less frequent than in a relaxed rock mass and they do not lose their geometrical continuity during settlement. This process takes much longer and is delayed compared to the layers of the relaxed roof. The phases of behavior of the rock mass follow one another and are connected with the increasing run along the strike of longwall face. In these phases there are differences related to the course of phenomena occurring in the roof of the longwall. A longwall face start-up phase can be distinguished. In the roof, blocks of rock are formed, which can fall freely. The impact of the support on the support in this period is negligible in relation to natural factors occurring in the longwall face. The next phase is the phase of incomplete caving, in which the goafs are already filled. The rubble rock is not yet tight and does not give proper support in relation to the rock layers that load the longwall face. Roof support capacity should cause mutual disintegration of the rock blocks between them in the roof of the longwall face. In the case of insufficient capacity of the support in the excavation, there may be signs of strong rock mass pressure. The last phase of a full caving occurs as the longwall runs progress, in the case of roofs that are prone to collapse. During the full creation of the caving, his zone achieves the largest possible range. Layers composed of rock blocks, over a longwall face and in the above-lying rock mass, obtain carrying capacity when the close contact of blocks is created. It results from the resistance of layers on one side to rubble rock caving and on the other hand to the boundary surface of the relaxed rock mass. The mechanized support is designed to help keep rock blocks contact by supporting them [1].

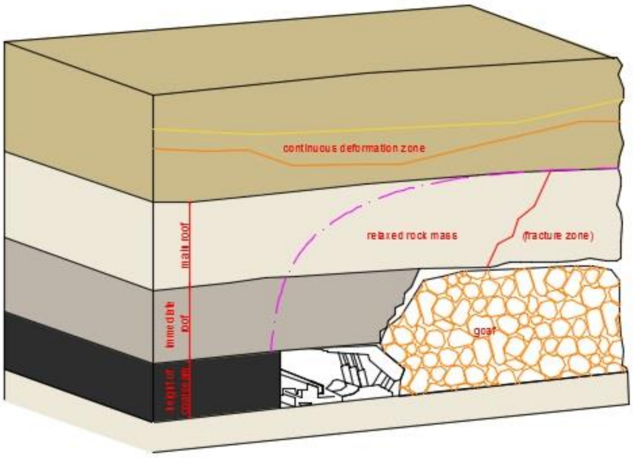

Fig. 1. Scheme of relaxed rock mass around longwall face with caving

3 Geological and mining within the mining area

Strength and structural parameters of coal and surrounding rocks were determined on the basis of boreholes no. LK.64 and LK.401 (Fig. 2). The average value of compressive strength for coal seam is equal 25 MPa. The depth of designed exploitation is equal 320 m. Immediate roof is built from siltstone, with varying thickness from 18.5m to 25m. Sometimes immediate roof is argillit glass format, with thickness from 0.2m to 0.6m. Compressive strength varies from 8 MPa to 163 MPa, (the average value is equal 45 MPa). Main roof is built from gritstone, with varying thickness from 9.3m to 14.3m. Compressive strength varies from 15 ÷ 272 MPa, (the average value is equal 70 MPa). Immediate floor is built from siltstone evenly distributed, sometimes is built from argillite. Compressive strength varies from 5 to 70 MPa, (the average value is equal 30 MPa).

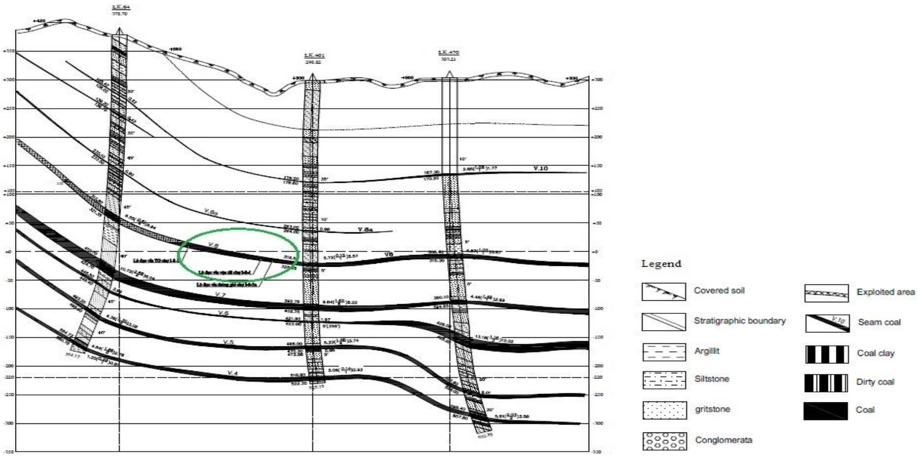

Fig. 2. Geological cross section through the boreholes

4 Geological and mining within the mining area Choice of powered roof support

The length of longwall face will have 93m and the length along the strike will have 355m. Designed longwall faces belong to coal seam no 8 and applies to the level from -20 to 0. The thickness of coal seams varies from 5.19m to 5.91m, (the average value is equal 5.54m). The height of first layer will be equal 3m. The inclination of coal seam varies from 5° to 15° (the average value is equal 11°). Coal seam has up to 2 clamping stones layers with a total thickness up to 0.5m (the clamping stones component is mainly clay). Coal seam will be divided into two layers. Within geological and mining conditions, powered roof support, type: FAZOS-15/31-POz (Fig. 3) was chosen [2]. The basic technical specifications of this support for the working conditions in the Vang Danh hard coal mine are shown in Table 2.

Table 2. Technical specifications of powered roof support FAZOS-15/31-POz

Feature	Value
Support height [m]	1.5 – 3.17
Operational height range (no burst of coal seam) [m]	1.7 – 3.0
Operational height range (coal seam prones to burst) [m]	1.8 – 3.0
Centre spacing [m]	1.5
Longitudinal inclination [°]	up to 35
Transverse inclination [°]	± 15°
Roof support advance [m]	up to 0.8
Number of hydrualic legs [-]	2
Diameter of leg [m]	0.2
Leg support capacity: setting load [MN]	0.785
Leg support capacity: yield load [MN]	1.508
Supply pressure [MPa]	25.0
Roof support capacity [MPa]	48.0

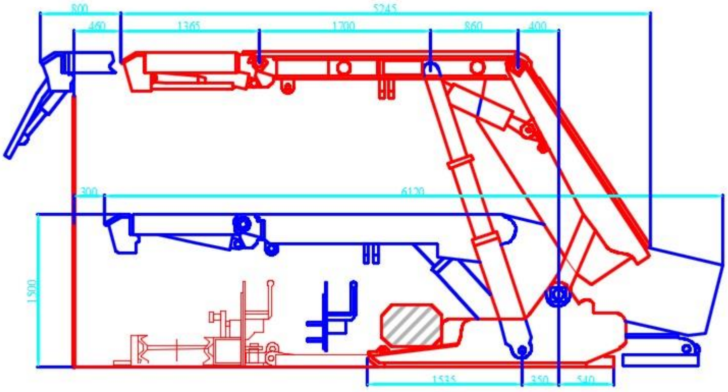

Fig. 3. Powered roof support FAZOS-15/31-POz

4.1 Load of the longwall face for the purpose of selecting the powered roof support [based on 4, 9-10]

The load of a longwall face, when the mechanized support is selected, is expressed by the value of the load moment of the M_Q which is the product of the load value of the excavation and its operating arm. For caving longwall faces with high compressive strength, it is calculated from the dependence:

$$M_Q = \frac{n_Q \cdot n_u \cdot a_p \cdot h_s}{\left(\frac{47,1}{R_c}+0,184\right)^2 \cdot (0,0025R_c+0,5)^{1,5}}, \text{ [MNm]} \tag{3}$$

where:
n_Q – coefficient of load intensities, [-],

$$n_Q = 1 \text{ for } 0.3 \le \frac{q}{R_{cz}} \le 0.5 \qquad (4)$$

$$n_Q = \frac{q}{R_{cz}} = \frac{8}{25} = 0.32 \qquad (5)$$

q – rock mass pressure, [MPa],
R_{cz} – compressive strength of coal in the seam, ($R_{cz} = 25$)[MPa],
n_u - coefficient of inclination, ($n_u = 1$, for inclination less than 20°), [°],
a_p - coefficient of periodic pressure, [-],

$$a_p = a_{p1} \cdot a_{p2} \qquad (6)$$

$$a_p = 0.508 \cdot 1.44 = 0.73 \qquad (7)$$

a_{p1} – coefficient taking into account the influence of suspended over goaf by rigid layers forming the solid roof rock mass for $Rc \ge 40$ MPa,

$$a_{p1} = \frac{1}{\frac{25}{R_C - 40} + 0.3} + 1 \qquad (8)$$

$$a_{p1} = 0.508$$

a_{p2} – coefficient taking into account the influence of suspended over goaf by rigid layers with a thickness greater than $3h_s$, lying above the solid roof rock mass up to a distance of $10h_s$ from the roof of the longwall face,

$$a_{p2} = -0.04 \cdot \left(\frac{h_b}{h_s}\right)^2 + 0.4 \cdot \frac{h_b}{h_s} + 1 \qquad (9)$$

$$a_{p2} = 1.44$$

where:
h_s – reduced height of longwall face, [m],

$$h_s = 0.8 \cdot H, [m] \qquad (10)$$

H – height of longwall face, [m]
R_c – a real roof compressive strength, determined of the basis of in situ tests in a given field of exploitation, (Rc = 55), [MPa],
h_b – in the calculations it was assumed that $h_b = 3$, [m],

$$M_Q = \frac{1 \cdot 1 \cdot 0{,}73 \cdot 2{,}4}{\left(\frac{47{,}1}{55} + 0{,}184\right)^2 \cdot (0{,}0025 \cdot 55 + 0{,}5)^{1{,}5}} = 3.181 \text{ [MNm]} \qquad (11)$$

4.2 Determination of roof support capacity [based on 4, 9-10]

The average roof support capacity (Pz) in the longwall face should be calculated for the least favorable case, i.e. for the length of face in which the support is moved. In the ongoing course of reasoning, application to the moment of load of the face, the supportive moment of the mechanized support in the excavation is used, this value is determined by the dependence:

$$M_P = P_Z \cdot l_z \text{ , [MNm/m],} \qquad (12)$$

where:
l_z - the operating arm of the support force of the powered roof support, ($l_z = 4$), [m],
P_z – average roof support capacity in a given longwall face, dteremined in MN per 1m section of face, perpendicular to the longwall front, calculated from the dependence:

$$P_Z = \frac{i \cdot n_k \cdot n_w \cdot P_r}{3 \cdot b}\left[\frac{(1-n_o)\cdot(d_{02} - d_{01})}{\frac{100 \cdot e^{-3{,}5 \cdot e^{-8 \cdot n_{cz}}}}{Z_{śr}} + \left(1 + e^{-1{,}8 \cdot e^{-2 \cdot n_{cz}}}\right)} + 2 \cdot n_m \cdot n_o\right] \text{, [MN]} \qquad (13)$$

where:
i – number of hydraulic legs, [-],
n_k - the reduction factor of the leg's capacity, taking into account its deviationin relation to the perpendicular to the base, ($n_k = 1$),
n_w - the transfer coefficient of the capacity of support to the roof of the face, dependent from the support span, for caving faces:

$$n_w = 1 - 0{,}4 \cdot e^{-7 \cdot e^{-0.5 \cdot L_w}} \tag{14}$$

$$n_w = 1 - 0{,}4 \cdot 2.71^{-7 \cdot 2.71^{-0{,}5 \cdot 4.70}} = 0.79 \tag{15}$$

where:
L_w - the sum of the roof length of support, the width of the "path" at the face of the longwall and the cut depth of shearer loader, ($L_w = 4.70$), [m],
P_r - leg support capacity: yield load [MN],
b - centre spacing, counted along the longwall face, [m],
n_o - value of the setting to yielding load ratio in the hydraulic legs, [-],,
n_m – coefficient of impact of floor strength ($n_m = 1$),
n_{cz} – coefficient of work of powered roof support ($n_{cz} = 1$),
d_{01} - the distance of the support leg from the face of the longwall, counted on the roof, before the start of mining, ($d_{01} = 3.3$) [m],
d_{02} - the distance of the support leg from the face of the longwall, counted on the roof, after completion of mining, ($d_{02} = 4.1$) [m],
$Z_{śr}$ - the average clamping value of the excavation over its span, equal to $d_{02} - d_{01}$, ($Z_{śr} = 9.44$), [mm].

$$P_Z = \frac{2 \cdot 1 \cdot 0.79 \cdot 1.508}{3 \cdot 1.5}\left[\frac{(1-0.52)\cdot(4.1-3.3)}{\frac{100 \cdot 2.71^{-3.5 \cdot 2.71^{-8 \cdot 1}}}{9.44}+\left(1+2.71^{-1{,}8 \cdot 2.71^{-2 \cdot 1}}\right)} + 2 \cdot 1 \cdot 0{,}52\right] = 0.57 \text{ [MN]} \tag{16}$$

$$M_P = P_Z \cdot l_z = 0.57 \cdot 4 = 2.28 \text{ [MNm/m]} \tag{17}$$

4.3 Determination the state of maintenance of the roof in the longwall face with caving

The method of determination the maintenance of the excavation depending on the load-bearing capacity of the longwall face support in the system with caving is based on the permissible deflection of the excavation roof and allows also determine the correct range of support [4]. In the method of this calculation, the size of the load index of "g" roof layers is subject to the ability to maintain their geometrical continuity over the excavation. The value of the load index of the roof layers depends on the average size of convergence calculated along the length of the excavation and depends on the relation of the support's capacity to the excavation load. Capacity of the support and the load of the excavation depends on natural factors, ie on the construction and properties of the rock mass, but also on technical factors resulting from human activity. The roof capacity index is calculated from the formula:

$$g = \frac{1}{\frac{Z_{L1}}{Z_g} + 0{,}3} \tag{18}$$

where:
Z_{L1} - inclination of the roof occurring on the first meter of the excavation span measured in mm subsidence, per 1m of the roof span,

$$Z_{L1} = \frac{1}{0{,}012 \cdot \frac{M_P}{M_Q} + 0{,}02}, \text{ [mm]} \tag{19}$$

$$Z_{L1} = \frac{1}{0{,}012 \cdot \frac{2.28}{3{,}181} + 0{,}02} \tag{20}$$

$$Z_{L1} = 34.96 \text{ [mm]}$$

Z_g - the limit value of the roof inclination formed from a given type of rock, above which it becomes a set of loose rock blocks, also counted in mm subsidence, per 1m of the roof span,

$$Z_g = \frac{k_e}{\frac{0,05}{R_c} + 0,006}\text{, [mm]} \tag{21}$$

where:

k_e – coefficient dependent on the mining system (for caving, $k_e = 1$),

R_c – real roof compressive strength, determined on the basis of tests in a given field of exploitation, (Rc = 55), [MPa],

$$Z_g = \frac{1}{\frac{0,05}{55} + 0,006} = 144.736 \text{ [mm]} \tag{22}$$

considering the dependence of Z_{l1} and Z_g, the load capacity index of the roof "g" was calculated:

$$g = \frac{1}{\frac{Z_{L1}}{Z_g} + 0,3} = \frac{1}{\frac{34.96}{144.736} + 0.3} = 1.84 \tag{23}$$

The value of the load index of the roof below 0.7 indicates very poor conditions for roof maintenance, which may mean a risk of a roof fall. Values in the range from 0.7 to 0.8 indicate that the condition of maintaining the roof is difficult. A value equal to 0.8 or more indicates correct roof maintenance.

5 Summary

The selection of a powered roof support for the geological conditions of the Vang Danh hard coal mine in Vietnam at a depth of around 300m is important for safe and efficient exploitation. Based on the calculated load capacity of the roof "g", it can be stated that the FAZOS-15/31-POz support has been well chosen and can provide workplace safety and can be a decisive factor in the effectiveness of exploitation conducted in geological and mining conditions of individual longwalls. Due to the complexity of the problem of cooperation of mechanized support with the roof rock mass, mathematical models obtained as a result of theoretical research and experimental research conducted in mining conditions should be used. In the case of a longwall face, fall of roof rocks may occur, which contribute to the loss of fluidity of the coal production process in the longwall, and also contribute to the increase of accident hazards for the working crew. Contemporary, modern underground hard coal mining is characterized by monitoring systems of mechanized support by roof loads, thanks to which it is possible to inform the crew in a very quickly and safety way and precisely identify potential danger zones. In order to apply the prediction of the load, tests and calculations in real conditions first must be performed, which will then be applied in numerical algorithms. The use of solutions of Polish Universities, Research Institutes as well as mining companies can be successfully implemented for the underground conditions of mines in Vietnam.

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