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THE INFLUENCE OF THE GEOMETRICAL CONSTRUCTION OF THE POWERED ROOF SUPPORT ON THE LOSS OF A LONGWALL WORKING STABILITY BASED ON THE PRACTICAL EXPERIENCE

This article focuses on the difficulties in ensuring longwall stability resulting from the wrong geometric form of the structure of powered support sections. The authors proved, based on the in-situ measurements and numerical calculations, that proper cooperation of the support with the rock mass requires correct determination of the support point for the hydraulic legs along the length of the canopy (ratio), as well as the inclination of the shield support of the section of the powered roof support. The lack of these two fundamental elements may lead to roof drops that directly impact the production results and safety of the people working underground. Another matter arising from the incorrect geometric form of the construction are the values of forces created in the node connecting the canopy with the caving shield, which can make a major contribution to limit the practical range of the operational height of the powered roof support (due to interaction of powered support with rockmass) in terms of the operating range offered by the manufacturer of the powered support. The operating of the powered roof support in some height ranges may hinder, or even in certain cases prevent, the operator of powered support, moving the shields and placing them with the proper geometry (ensuring parallelism between the canopy and the floor bases of the section).

Keywords: powered roof support, stability, longwall, roof fall

1. Introduction

The issue related to correct cooperation of powered roof support sections with the rock mass surrounding a longwall excavation is one of the most important factors determining the safe and effective operation of the longwall system for hard coal deposits. In given mining and geological conditions, in which a longwall of a certain length and height of extraction is located, only

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a limited impact can be made to control the value of the load imposed by the rock mass [8,15,19]. Therefore, all aspects related to the broadly understood selection of a support that include the geometrical form of the structure of the section as well as the load-bearing capacity (strength) of the mounted hydraulic legs are relevant. Unfortunately, based on the author's observation, in practice, mines and some mining equipment manufacturers underestimate the importance of the impact of the geometrical form of the powered roof support section on longwall stability. Most often, the selection of powered roof support sections is limited to checking whether the height of the designed longwall is within the height of the powered roof support sections provided by the manufacturer. Such a simplified approach may result in significant difficulties in maintaining the longwall and consequently in preventing the achievement of the assumed level of extraction [20].

This article focuses on some aspects related to the loss of longwall stability (roof fall or/and cave-in) resulting only from the incorrect geometrical form of the structure of the powered support section. Incorrect geometrical form of the section concerns, in particular, two aspects – the ratio of the canopy (selection of a suitable support point for the hydraulic legs along the canopy) and the inclination of the complete shield support of the powered roof support. Canopy ratio is technical parameters ensuring that the balance of mass forces originating from the surrounding rock mass is maintained include the uniform distribution of pressure forces along the entire length of the canopy. The distribution of pressure forces can be achieved on condition that the position of the resultant force is maintained at a distance of approximately 1/3 from the end of the canopy [24]. Underground observations and in-situ tests occurred difficulties in conducting longwalls confirm that the abovementioned aspects supplemented with calculations of the roof load index value "g" [4] and floor support analysis [10,11,25] are necessary for research focused on predicting the stability of longwall excavations located in specific mining and geological conditions, in which a specific type (geometric form of the section and strength in all the hydraulic legs) of the powered roof support section is planned to be used or have already been applied. It is obvious that when a longwall excavation is exposed to dynamic loads resulting from tremors, to ensure the excavation stability and, above all, the safety of miners, it is necessary to analyse the additional excavation load and the capacity of the entire hydraulic system together with the relief valve protecting the hydraulic leg against damage [17,21,27,28,30].

Therefore, on the basis of concrete in-situ observations and tests ,the purpose of this article is to draw attention to issues related to an incorrect geometrical form of the structure of the powered roof support section, which undoubtedly affects the level of miner safety and production results and may be one of main reasons for the occurrence of a roof rock cave-in in the longwall. Other factors include incorrectly selected section support, failure of the section support and errors made by section operators [26].

2. Canopy ratio − selection of a suitable support point for the hydraulic leg along the canopy of the powered roof support section

One of the basic parameters characterizing a given type of powered roof support and provided by the manufacturer is its initial and operational support values. These values, for a given section's structure, result from the internal diameter of the hydraulic legs, the set supply pressure and working pressure, the number of hydraulic legs, their inclination in relation to the canopy and its surface. The calculated unambiguous support values most often expressed in MPa or t/m^2 are used when selecting powered roof supports using GRC curves [2,3,18]. Other significant calculations regarding the destruction and detachment of the sidewall whose stability in many cases impacts the stability of the entire longwall excavation [1,6,33,35] also include calculated and reported supports of the powered support section. At the same time, bench tests [3] or analytical calculations [7,8,19] have shown that the distribution of impacts along the entire length (surface) of the canopy is not homogeneous. The highest pressure values are obtained in the rear part of the canopy (behind the hydraulic legs, from the cave-in side) and the lowest, sometimes falling to zero, at the end of the canopy at the face of the longwall. The values of these pressures, and thus their distribution on the canopy, with the correct installation (setting) of the section and the specific working height, depend on the geometric form of the section structure and the strength of the hydraulic legs. The canopy ratio, which describing a hydraulic leg socket distance in relation to the end of the canopy at a proportion of max. 2.6:1 [24], is significant because of the distribution of impacts imposed by the canopy on the longwall roof. The recommended maximum value for this parameter should be in the range of 2.0 to 2.5 [5] or up to 2.7 [6,12]. The lower ratio values given in the range are recommended for direct roof rocks characterized by low strength parameters and/or prone to falling after completing a web. Larger values from the given range can be used for direct roofs with higher strength parameters.

Newly designed sections in Polish mines are equipped with a canopy approximately 3.8 m to 5.4 m long. In some cases, the length of the canopy has almost doubled in relation to the structures used until the end of the 1990s. The increase in the length of the canopy results, among other reasons, from the need to comply with the regulations provided by the Polish law regarding the width of the walkway (minimum of 0.6 m), taking into account the possibility of building additional cooling devices in the walkway (minimum of 0.35-0.50 m), over the years the increase in the width of the longwall conveyors used (approximately 0.3-0.5 m) and the necessary space for the foundation of the shearer and ensuring the minimum length of the path of the shearer (tip-to-face distance). At this canopy length, reaching the recommended value of the canopy ratio in the range 2.0-2.7 seems possible only in longwalls over 3.8 m-4.0 m high, where the walkway will be located behind the hydraulic legs (rear walkway) [13]. In lower longwalls, taking into account the requirements resulting from the regulations (minimum walkway with the support pushed closer to the longwall conveyor) and the requirements of users (mines) as to the minimum length of the canopy, achieving the recommended value of the canopy ratio is practically impossible.

The conviction that it is impossible to provide a value up to a 2.7 ratio on the canopy, and thus the proper distribution of forces in a longwall up to 3.5 m high, has been proven to be correct. One of the coal producers in Poland announced a tender for the supply of a section of lemniscate powered supports with two hydraulic legs with a construction height range of 1.4 m to 3.4 m, intended for work in a longwall with low strength parameters of the direct roof. In response, manufacturers offered 8 different types of powered support sections that meet the requirements of the tender. The lengths of the canopies in individual designs of the section ranged from 3,800 mm to 4,880 mm (three types up to 4.0 m long, one between 4.0 and 4.5 m and four over 4.5 m). The canopy ratio values ranged from 3.05 to 4.88. Using the mathematical model developed in GIG [14], all the offered section types were subjected to appropriate calculations regarding the influence of their geometric construction form (including canopy ratio and hydraulic leg inclination) on distribution supports along their canopies. Calculations have shown that in each of the analysed structures of powered roof support sections, there was a section (surface) on the canopy on which there is no pressure resulting from the force in the hydraulic leg (so-called active roof support). The length of this section varied for individual section designs and ranged from 258 mm to 1385 mm. It is obvious that these results were closely related to the values of the canopy ratio of individual structures. The higher the ratio was, the longer the section without active support (e.g., ratio 3.05 – section length 258 mm; ratio 4.88 – section length 1385 mm).

A numerical program UDEC 4.0 was used to determine the impact of the canopy ratio on the cooperation of the support with the rock mass and thus also the stability of the longwall excavation [31]. A numerical model corresponds to the actual observed (registered) geological and mining conditions in which the longwall mining in panel No. 121 is based on caving system. A variant operation of a two-leg powered roof support section with a defined length of canopy and support of hydraulic legs was simulated in such conditions. Individual variants differed only in the geometrical form of the structure in terms of the canopy support point on its length (canopy ratio). Numerical model was calibrated based on the in-situ measurements of roof fall in working of a longwall panel No. 121 for a given geometry form of structure of the 2-leg shield as shown in Figure 1.

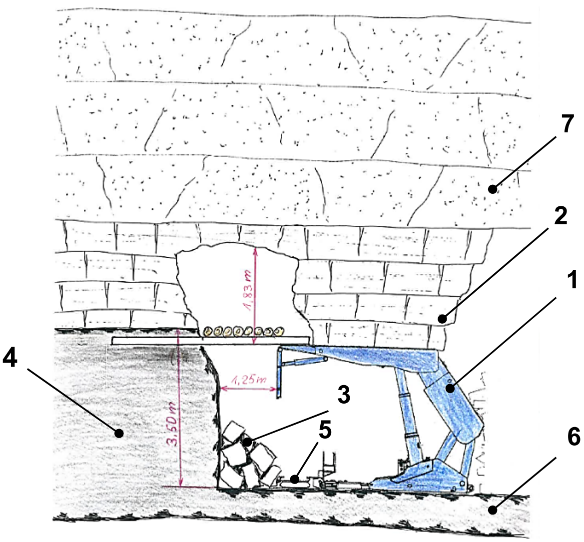


Fig. 1. The in-situ measurement of the rock mass around the longwall working and its geological profile: 1 – 2-leg shield, 2 – immediate roof (shale), 3 – roof fall, 4 – coal seam, 5 – armored face conveyor, 6 – floor (shale), 7– main roof (sandstone)

2.1. Numerical model

Research on the impact of changes in the distribution of load-bearing capacity along the length of the canopy of the powered roof support section on the stability of a longwall excavation based on a system with roof cave-in was carried out on a two-dimensional model and a disc 70 m long and 86.3 m high. This model, made in the UDEC 4.0 code, reflects the actual mining conditions of a longwall at a depth of 877 m (Fig. 2). The 70 m long disc reflects the the section on which lithological profile in-situ measurements were taken in the longwall panel No. 121.

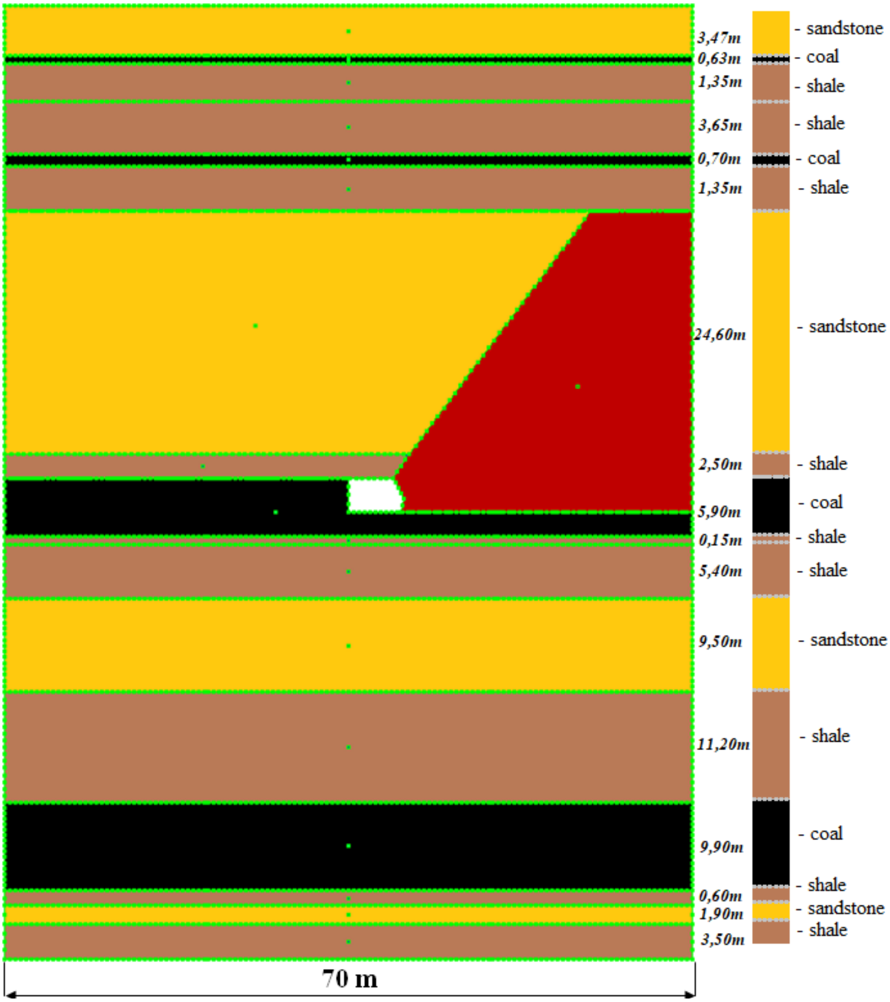


Fig. 2. Numerical model of the rock mass around the longwall excavation and its geological profile

UDEC code (Universal Distinct Element) was adopted for two-dimensional behaviour analysis of longwall panel, which the response of discontinuous media under the condition of static loading. The UDEC method was based on the following features:

- the rock mass is simulated as a blocks (layers) which interact by contact through block and corner,
- boundary interaction between blocks are regarded as discontinuities,
- method allows to calculation the behavior of large displacements and non-linear constitutive for discontinuities based on dynamic algorithm.

The direct roof of the 5.9 m-thick operated coal seam, where the analysed longwall excavation is located, is composed of a 2.50 m clay shale layer, above which there is a 24.60 m thick sandstone layer. A coal layer below the 5.55 m-thick shale layer is deposited beneath the extracted coalbed.

2.2. Assumptions for the numerical model

The conventional Mohr-Coulomb elasto-plastic model was used to represent shear failure in rocks, where elastic models define the stress states which cause the plastic deformation in the rock mass. The rocks material behaves in an isotropic manner, which means that the behaviour of the rock mass is identical in all directions. The material in this medium has the features of a homogeneous continuous medium, which manifests itself in a linear characteristic in the strain-stress system without the effect of hysteresis when unloading. The basic parameter of the model is the volumetric stiffness modulus K interpreted by the formula:

$$K = \frac{E}{3(1-2\nu)} \tag{1}$$

and the shear modulus G defined by:

$$G = \frac{E}{2(1+\nu)} \tag{2}$$

Table 1 presents the parameter values characterizing the real layers of the modelled rock mass in the vicinity of the analysed longwall excavation.

TABLE 1

Strength parameters of the layers of the tested rock mass adopted for calculations

Type of rock	ρ kg/m^3	ν –	E GPa	K GPa	G GPa	R_c MPa	φ deg	c_M MPa
shale	2400	0.29	11.1	8.8	4.3	22	25.25	5.9
sandstone	2700	0.38	12.0	16.6	4.3	28.65	25.2	8.2
coal	1450	0.3	4.2	3.5	1.6	15.4	24.55	8.7
goafs	1440	0.4	0.6	1.0	0.2	—	13	—

Symbols: ρ – bulk density, ν – Poisson's ratio, E – Young's modulus, K – bulk stiffness modulus (Helmholtz modulus), G – dimensional stiffness modulus (Kirchhoff modulus), R_c – ultimate resistance to uniaxial compression, φ – internal friction angle and c_M – cohesion in the massif.

Discontinuities at the contact border between the rock layers that compose the rock mass model are described by the elasto-plastic model with slip and surface contact for the average parameter values listed in Table 2.

TABLE 2

Parameters of rock mass discontinuity [31]

Type of discontinuity	Normal stiffness GPa/m	Tangential stiffness GPa/m	Int. friction angle [°]
in sandstone	10.0	1.0	30.0
in shale	10.0	1.0	27.0
in coal	1.3	0.5	29
between shale and coal	3.3	2.0	15.0
between sandstone and coal	2.9	2.2	12.0

The model includes the following boundary conditions [23,34] as a the limit of the model:

- lower and upper edge: displacement condition (velocity $y = 0$),
- side edges: displacement condition (velocity $x = 0$),
- hydrostatic stress state,
- deposit fall angle 0°,
- cave-in angle equal to 65° for roof rocks, which are characterized by compressive strength in the range between 19.6 and 29.42 MPa according to [18],
- model subjected to gravity $g = 9.81$ m/s^2.

The primary pressure of the rock mass was interpreted by the relationship defined by:

$$q = 0.02 \cdot G \cdot m_c \cdot \cos\alpha \tag{3}$$

where the m_c parameter was adopted at the level of 0.5. The results are presented in Figure 3.

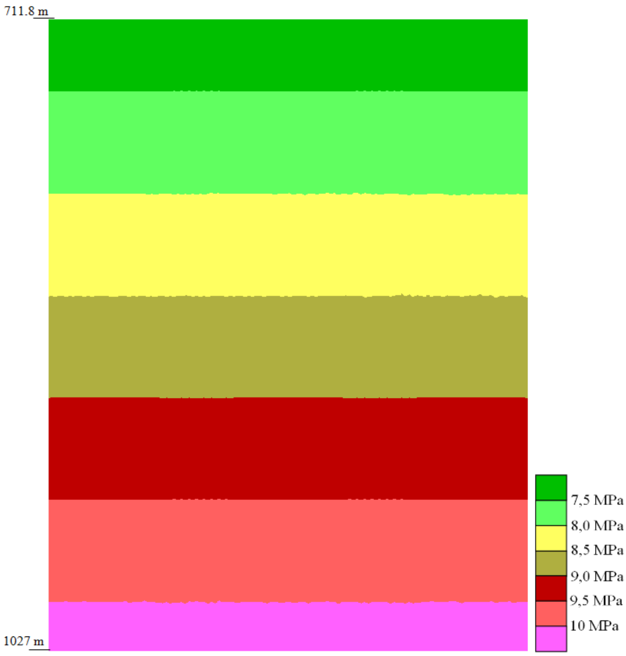


Fig. 3. Map of the primary pressure distribution in the rock mass model as a result of implantation of the relationship (3) in the UDEC program

The values of ranges of caving zone and the fracture zone in the rock mass model were defined on the basis of the relationship proposed in the work [32] for medium-strong rocks in the strength range between 20 and 40 MPa:

$$h_{z(s)} = 100g/(c_{z1(s1)} \cdot g + c_{z2(s2)}) \tag{4}$$

where

c_{z1} — constant for average cave-in height ($c_{z1} = 4.7$), m,

c_{z2} — constant for average cave-in height ($c_{z2} = 19$), m,

c_{s1} — constant for average fracture height (c_{z1} = 1.6), m,
c_{s2} — constant for average fracture height (c_{z2} = 3.6), m,
g — coalbed thickness, m,
h_z — average cave-in height, m,
h_s — average fracture height, m.

The powered roof support used in the longwall panel No. 121, operating at a height of 3.5 m, was simulated in UDEC (Fig. 4) with a beam element. The variant II of surface pressure distributions on the canopy and floor base of the powered roof support were included in the model of the shield (Figs. 5 and 6b). The variant I and variant III are theoretical and are the results of a hydraulic leg position change in direction of coal face (variant I – Fig. 6a) or in direction of roof fall (variant III – Fig. 6c)

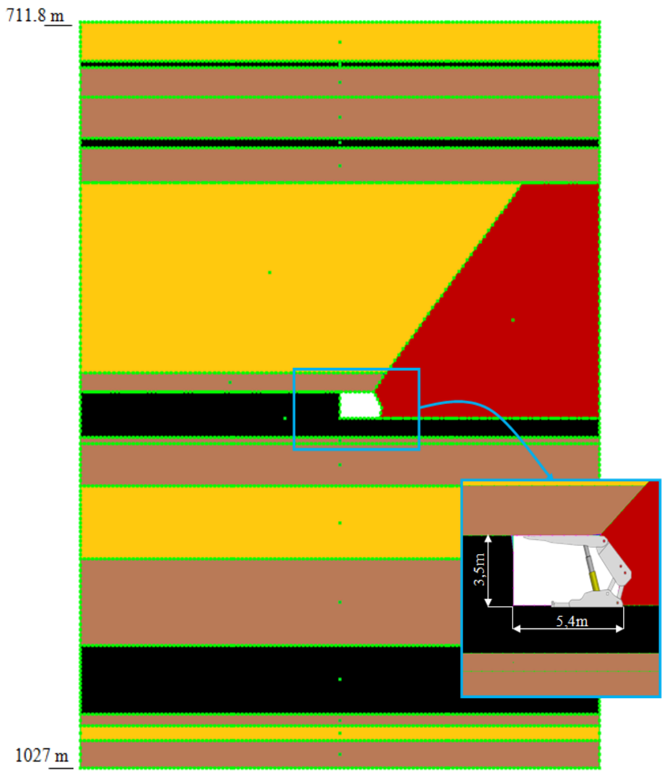


Fig. 4. The complete view of geometric model of rock mass with a simulation of a powered roof support

The following properties of the beam element were considered:
a) strength parameters:
 – density 7850 kg m^{-3},
 – Young's modulus 2.1e^{11} Pa,
 – Poisson's ratio 0.29,

b) strength parameters describing the contact between support and the rock:
   – residual tensile strength $6.9e^8$ Pa,
   – friction angle 26.9°,
   – normal stiffness $1.0e^9$ Pa,
   – shear (tangential) stiffness $1.0e^9$ Pa.

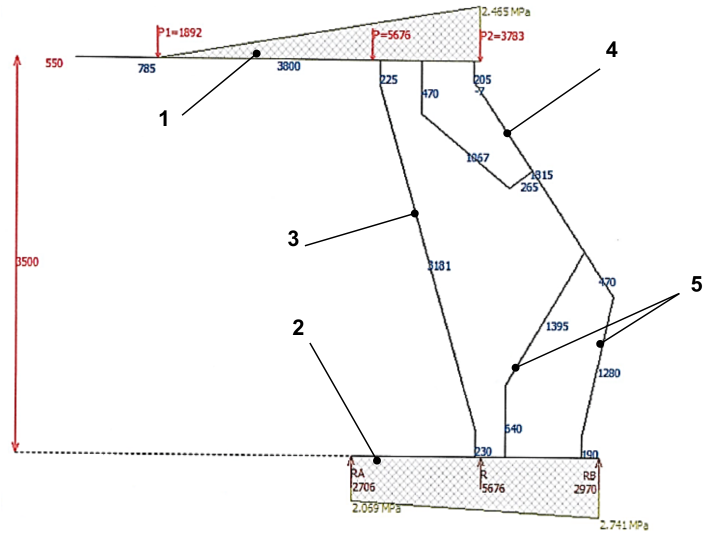


Fig. 5. Distribution of forces and pressures on the canopy and floor base of the powered roof support: 1 – canopy, 2 – floor base, 3 – support (hydraulic leg), 4 – caving shield and 5 – lemniscate connectors

The analysis covered a section equipped with two legs (single-row support) operating at a height of 3.5 m. The geometry of the powered support is a canopy (Fig. 5-1) with a length of 3.8 m, connected via a hydraulic leg (Fig. 5-3), with a length of 3.181 m, with a floor base (Fig. 5-2) 2.36 m long. The whole system is additionally connected with a 1.815 m long shield support (Fig. 5-4) and with a system of two pairs of lemniscate connectors with lengths of 1.395 m and 1.280 m (Fig. 5-5). Calculations were performed for the technical parameters of the powered support section as follows:

– coefficient of friction at the canopy-roof border $\mu = 0.3$,
– operation range of the support – 1.9-3.6 m,
– section width – 1.5 m,
– diameter of the hydraulic leg ø300 mm (1st stage)/ø245 mm (2nd stage),
– support advancing force (supply pressure – 25-32 MPa) – 1.76-2.12 MN,
– working advancing force (working pressure of 38 MPa) – 2.968 MN.

As mentioned earlier, to demonstrate the impact of changes in the length of the canopy section on which there is active support of the roof (depending on the canopy ratio) on the stability of the longwall excavation, its three calculation variants were analysed:

– **variant I** includes active support along the entire length of the canopy with a length equal to 3.8 m – **ratio 2.24 (Fig. 6-a)),**

- **variant II** includes real active support on a 3.015 m-long section of the canopy (no active support at a 0.785 m-long section of the canopy) – **ratio 3.20 (Fig. 6-b)),**
- **variant III** includes active support on a 2.565 m-long section of the canopy (no active support on a 1.235 m-long section of the canopy) – **ratio 4.10 (Fig. 6-c))**.

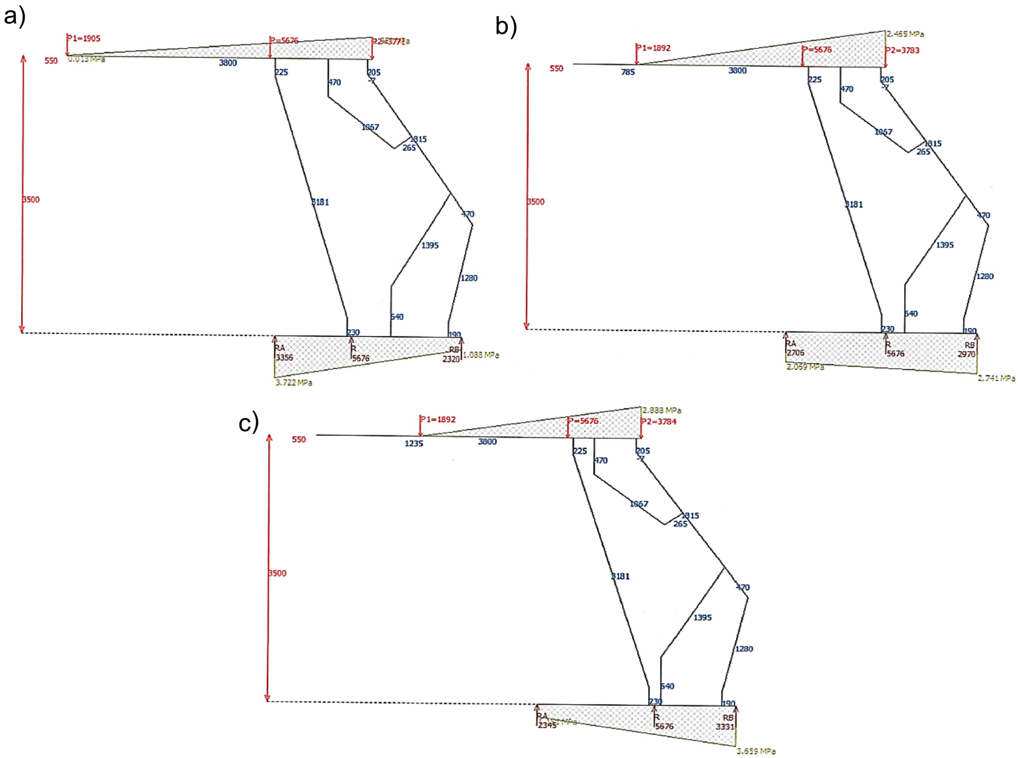


Fig. 6. Calculation variants included in the numerical calculations: a) ratio 2.24 – variant I, b) ratio 3.20 – variant II and c) ratio 4.10 – variant III. Additionally, figures on the length of the individual elements and the distribution of section pressure on the roof and floor of the excavation are marked

The values of the canopy ratio factor for individual calculation variants are as follows: 2.24 (variant I), 3.20 (variant II) and 4.10 (variant III). "Real" – the geometry of the powered support section applied in practice with parameters described earlier is presented in option II. Variants I (leg moved 268 mm towards the face of the wall – in relation to variant II) and III (leg moved 160 mm towards the cave-in – in relation to variant II) are theoretical and were obtained by moving the mounting space of the leg along the canopy.

Figure 7 shows the distribution of load changes on the roof and floor of the rock mass that was adopted for calculations in the developed numerical model. The distribution of load changes was applied to the beam (Fig. 7-1), which interacts with rock mass and simulates the behaviour of 2-leg shield in numerical model.

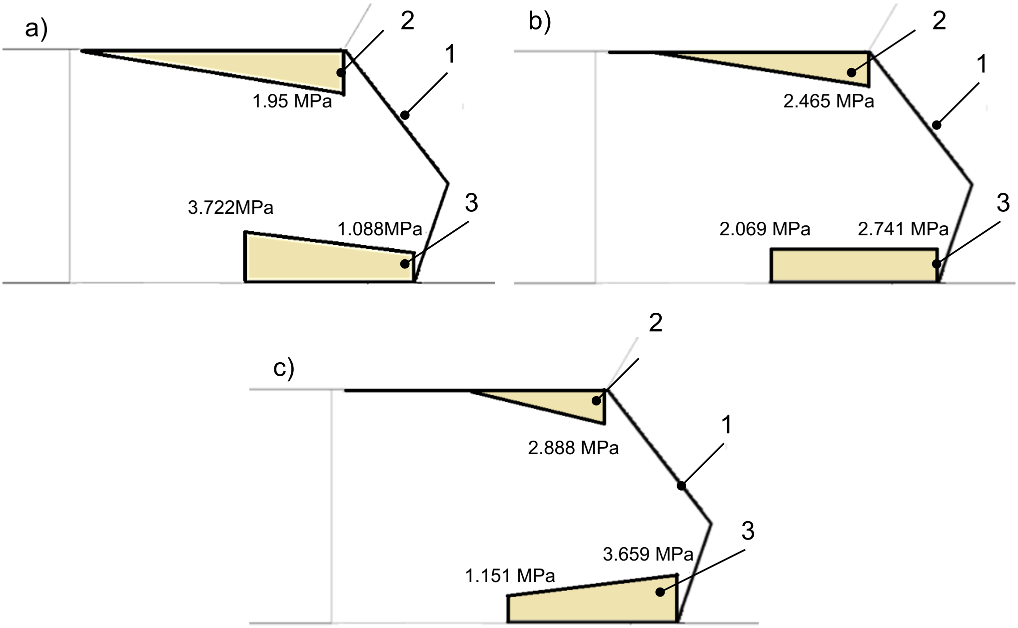


Fig. 7. The value and distribution of loads along the roof (2) and floor (3) of the rock mass and beam element (1) in the developed numerical model: a) ratio 2.24 – variant I, b) real ratio 3.20 – variant II and c) ratio 4.10 – Variant III

Numerical calculations included changes in the distribution and load values on the canopy and floor base depending on the canopy ratio (Fig. 7) and for the situation prior to and after carrying out a web of 0.80 m, while taking into account a 0.55 m-wide shearer path.

Numerical simulations were carried out on 6 models and are presented in Tables 3 and 4. Figure 8 indicates that the value of the canopy ratio for a given section structure (using the same supports (strength) of hydraulic legs) can have a significant impact on the stability of a longwall excavation and the possibility of a roof cave-in. The criterion of damage zone was numerical simulation of displacement of roof rocks in working of a longwall.

Calculations based on this model have shown that adequate stability of the roof in specific mining and geological conditions of a longwall requires both proper section support and proper distribution on the canopy. Correct distribution requires correct selection of the canopy support point(s) provided by the hydraulic legs. Depending on the location of such a point on the canopy and thus describing it using the canopy ratio, various longwall operational conditions may occur related to ensuring adequate stability of its direct roof. The analysis that covered the roof conditions of the longwall and the three variants of the geometrical form of the section has shown that the damage zone of roof rocks in the area of the frontal walkway can change practically from zero to a height of approximately 1.15 m before the web up to approximately 3.0 after the web. The comparison of the calculations for the support sections made according to variants I and II – ratio 2.24 and 3.20, respectively, clearly indicates that the lack of active support on a section approximately 0.8 m long results in the creation of a damage zone in the roof with a height of 0.2 m before the web and up to approx. 2.0 m after the web. In the case of a section with a geometrical

TABLE 3

Visualization of the damage zone of roof in a longwall working for individual calculation variants using the UDEC 4.0 program

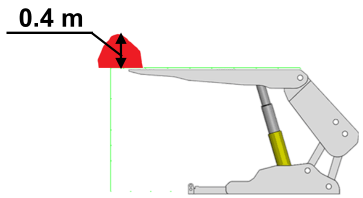
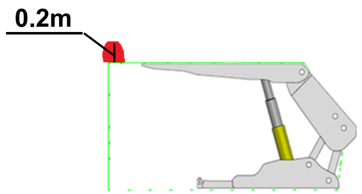
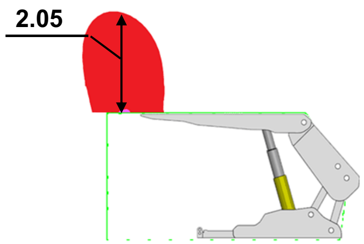
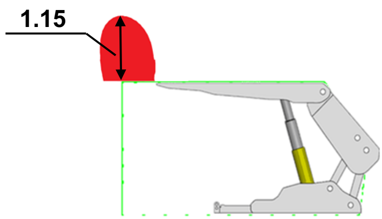
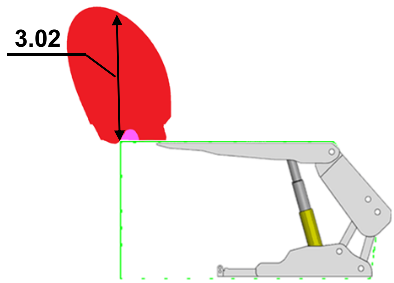
Web, [m]	Path, [m]	Calculation variant
Variant I – ratio 2.24		
0	0.55	—
0.8		
Variant II – ratio 3.20		
0	0.55	
0.8		
Variant III – ratio 4.10		
0	0.55	
0.8		

TABLE 3

List of the results of numerical calculations of the impact on working stability of longwall No. 121 of the canopy ratio (active support) of the 2-leg shield

Technical parameters			Roof
Path, [m]	**Web [m]**	**Canopy ratio**	**Range of the damage zone [m]**
0.55	0	Variant I – ratio 2.24	0
	0.8		0.4
0.55	0	Variant II – ratio 3.20	0.2
	0.8		2.05
0.55	0	Variant III – ratio 4.10	1.15
	0.8		3.02

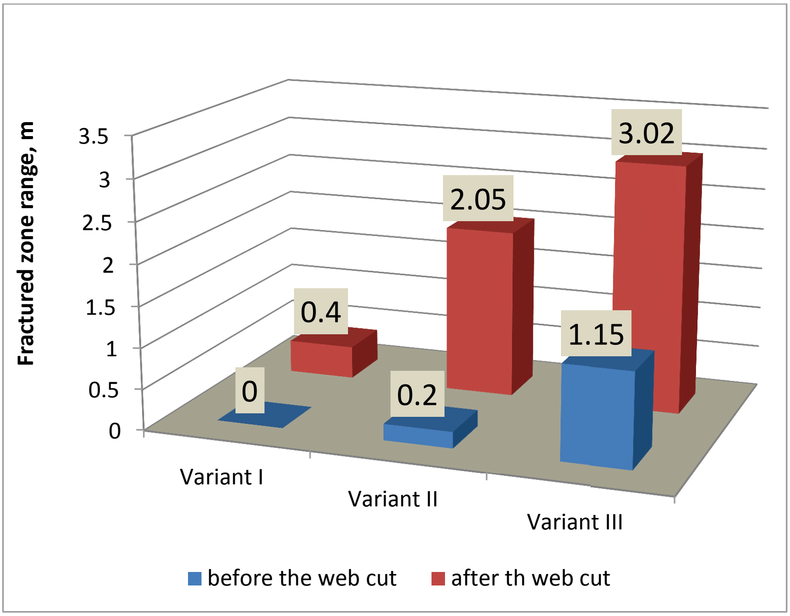


Fig. 8. Distribution of the damage zone in a longwall working roof depending on the change in the value of the canopy ratio (active support) of the 2-leg shield

form made as in variant III (approximately 1.25 m and no active support zone), its application would result in the creation of a roof damage zone to a height of approximately 1.1 m before the web and up to approximately 3.0 m after the web. It is highly probable that in such situation, the fall of roof rocks will occur and prevent proper cooperation of the support with the rock mass, reducing the longwall progress and increasing the risk of accidents. Although it is not possible to take into account the time factor in the calculations using UDEC 4.0, the obtained results make it possible to be aware of the level of increase in the risk of cave-in when the powered roof support is not moved quickly enough after the coal is excavated (comparison of calculation before and after the web cut).

3. Impact of the inclination of the shield support and its correction on the cooperation of the powered roof support section with the rock mass

The research team during underground testing and observations, occurred in longwall No. 121, focused on the fact that roof rocks fall often when powered roof supports operate at a height close to the lower operating range specified by the manufacturer. Most often, when the powered roof support works on the lower working ranges, the canopies are raised upwards and can take a form practically one surface with a caving shield. This arrangement of these two elements of the powered roof support section causes the canopy support cylinders to extend for the whole or almost the entire length [22]. In this case, the correction of the section geometry is more difficult (restoration of parallelism between the canopy and the floor base), and these cylinders may be more easily damaged. This is undoubtedly connected with the values of force occurring in the node connecting the section canopy with the support. To determine the value of this force and the direction of its operation depending on the structure of the section and the way (place) of installation of the support cylinder, a special model REF _Ref518377759 \r \h [15] and a calculation program were developed at GIG.

The model was used to analyse difficulties in longwall 124 in seam 510. Difficulties in ensuring the stability (roof fall) and at the same time damage to the support cylinders of the powered roof support section (45 pieces in total) were registered in longwall 124 with a support equipped with two legs with an internal diameter of 320 mm and a construction range of 2.4 m-4.6 m in height. The research team visited longwall 124 and measured the geometry of the powered roof support operation. The team found that due to the varying thickness of the exploited seam, part of the section at a certain section of longwall 124 operated at a height of approximately 3.0 m and remained at a height of 3.5 m as shown in Figure 9. At the same time, these sections were arranged in such way that they worked with canopies inclined upwards at an angle of 8° and 12° for a height of 3.0 m and 3.5 m, respectively [Figures 9 and 10].

The analysis of calculations and measurements regarding the section geometry and the change in the angle of inclination of the shield support depending on the height of the section work showed that the actual angle of inclination of the shield support during the operation at heights of approximately 3.5 m was approximately 20°, and at a height of 3.0 m it was 15°. If the correctness of the working geometry of the section had been maintained (parallelism between the canopy and the floor), these angles for working heights of 3.5 m and 3.0 m should have been approximately 24° and 31° respectively (Fig. 11). Thus, the actual values of the inclination of the shield support were significantly lower than the recommended value of 30° [5]. This horizontal arrangement of the shield support makes it easier for rock material to accumulate on it. Such material both loads the shield support and allows it to impose an additional load from the higher layers of the roof. Additional calculations of the value of force occurring in the joint node connecting the shield support and the canopy (marked as R5 in the program [15] and shown in Figure 12) depend on the geometrical form of the section (inclination of the canopy and shield support) and the load value of the shield support (Fig. 12).

In the case of the analysed section with a height range from 2.4 m to 4.6 m, a support cylinder was used with a maximum force of 588 kN under the piston and 703 kN over the piston. The calculations presented in the form of a graph (Fig. 12) show that the section operator did not have the possibility to correct the section geometry using a support cylinder because the forces

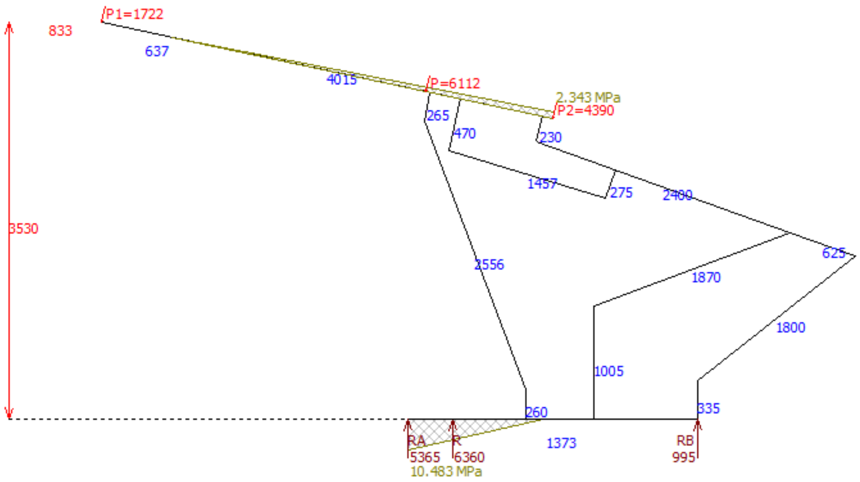


Fig. 9. Model of a section type 24/46 working in longwall 124 (actual geometry of the construction defined based on the in-situ observation), at a height of 3.5 m, with a canopy raised by 12° (additionally, figures on the length of individual elements and the distribution of section pressure on the roof and floor of the excavation are given)

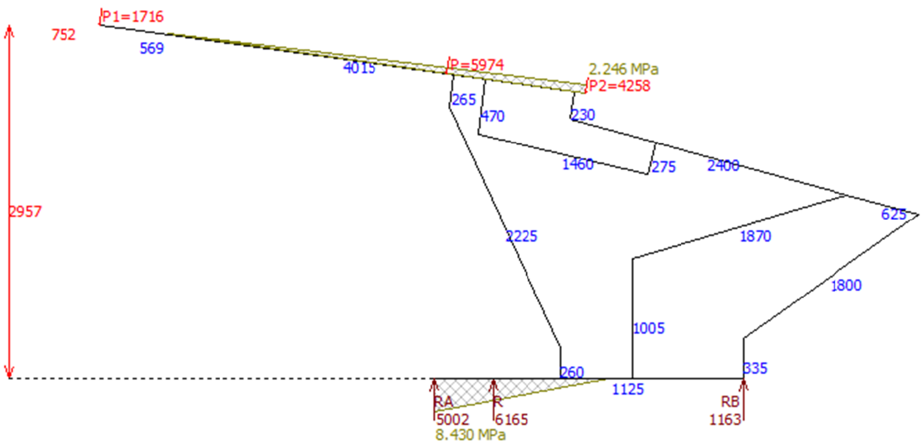


Fig. 10. Model of a section type 24/46 working in longwall 124 (actual geometry of the construction defined besad on tha in-situ observation), at a height of 3.0 m, with a canopy raised by 8° (additionally, figures on the length of individual elements and the distribution of section pressure on the roof and floor of the excavation are given)

occurring in this node of section 24/46 can be much higher in this operational range. In addition, when loosening the section, it had a natural tendency to form one plane through its canopy and shield support. The calculations thus explain the mechanism of damage [22] of both the support cylinders themselves and the blocking systems that were to prevent damage. The results show that at the lower working ranges of the analysed structure, even with the correct geometry of setting

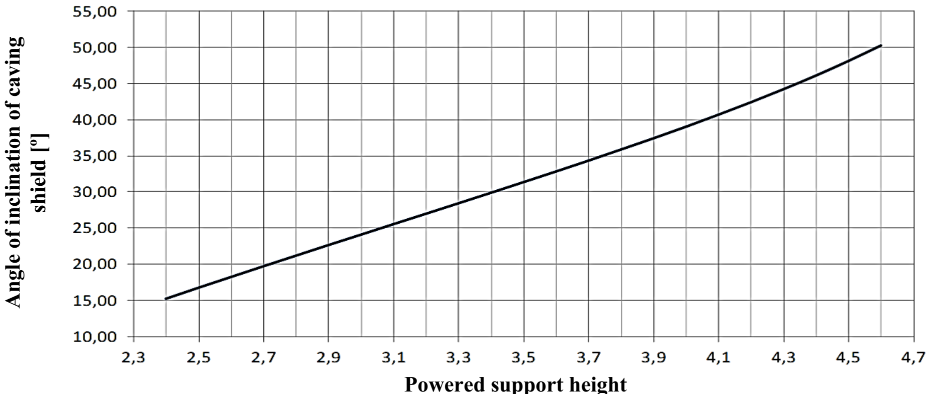


Fig. 11. Changes in the angle of inclination of the shield support of the 24/46 section depending on its installation height (for proper installation geometry)

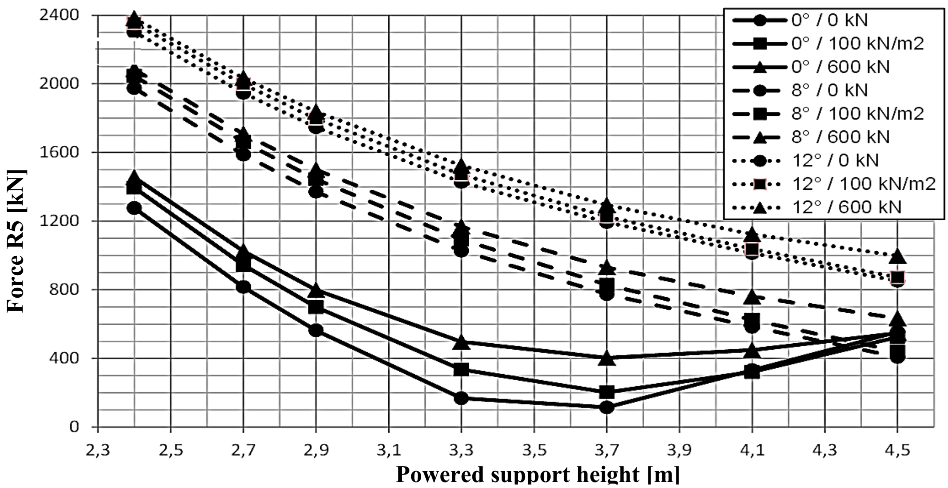


Fig. 12. Changes of R5 force in the girder joint node with the shield support for 24/46 type sections for various variants (values) of the shield support load and geometry of the construction (inclination angle of the canopy)

the force section in the R5 node (approximately 1400 kN), they almost double the values of the force in the support of the canopy (approximately 700 kN). Theoretically, in the case of operation of the analysed section structure at the lower height ranges with the canopy raised by approximately 12°, correct positioning requires the force corresponding to at least four support cylinders.

In addition to its inclination, the load value of the shield support is also undoubtedly related to its surface. It is natural that the larger the surface is, the greater the load. In the vast majority of cases, the surface (length) of the support increases as the range of operation of the section increases, and in the lower height ranges, the inclination of the cover is significantly less than

30^o. The above regularity is reflected in the analysed section design. Thus, the loss of stability of a longwall excavation caused by improper geometry of the section installation can have its source in its geometric form and/or in service errors (by operators). Diagram 3 developed for the construction of section 24/46 shows that in some operating ranges (approximately 2.9 m), additional loads on the shield support can cause additional forces in the R5 node, which cause the cylinder of the shield support to stretch spontaneously and raise the canopy when shifting and setting the section in a new position. For lower operating ranges of the analysed section 24/46, below the height of 2.8 m, the unfavourable "behaviour" of the section will occur irrespectively of the value of the support load. Therefore, the lower range of the height for this section should be 2.8 m and not 2.6 m, as specified by the manufacturer. Operation of the 24/46 section at these heights will cause it to switch automatically to "working mode" corresponding to the curve determined for the increased inclination of the canopy, where in some height ranges, for the R5 node, the force values may increase by up to 700%. This results in a loss of control over the correct installation of the section and consequently a loss of excavation stability and roof falls. In addition, the load on the protective cover [7,13] reduces the developed working support of the section. In the case of work of the analysed section 24/46 with incorrect geometry and heavy load of the shield support, it „loses" approximately 17% of its working support. This fact will undoubtedly have an additional impact on the difficulties in mining the area. This confirms the thesis mentioned at the beginning of the paper that it is very difficult, and sometimes even impossible, to construct a powered roof support with a large difference between the lower and upper operating range so that it works properly with the rock mass throughout the entire height range and ensures the stability of the longwall excavation.

4. Conclusions

The calculations and analyses presented in this paper, carried out on the basis of actual in-situ observations, indicate that the proper cooperation of the powered roof support section with the rock mass to ensure good longwall stability cannot be limited only to the load bearing capacity (strength) of the hydraulic legs. It has been shown that depending on the canopy ratio (in the examples shown, the change in the leg construction over a distance of approx. 500 mm) the range of the rock damage zone surrounding the longwall excavation and the possibility of falling roof rocks may significantly changes. It has been shown that the difficulties observed in longwall No. 121 in maintaining the roof can be limited in the case of using a powered roof support with different value of the canopy ratio (variant I instead of variant II).

Thus, the data characterizing the sections of the powered roof supports and concerning only the value of the canopy pressure on the roof is insufficient. To determine the conditions of cooperation between the section and the rock mass, it is necessary to know the distribution of support along the canopy. It is optimal that this support occurs over the entire length of the canopy. In some cases, however, particularly in the case of supports used in low longwalls, providing this condition may cause limitations on the length of the canopy. This is why it is significant to study the entire technical equipment of the longwall to limit the longwall span and thus the length of the canopy as much as possible.

Another important aspect that should be included in the design process of the powered roof support section, as demonstrated by the observations and analyses carried out, is the analysis of the values of the forces occurring in the node connecting canopy with caving shield (marked as R5), as well as the inclination (load) of the shield support. Failure to include these parameters may cause, in certain height ranges, the front of the canopy to spontaneously rise upwards when moving the section, and the shield support will tend to form one plane with the canopy. In most cases, such section geometry prevents its proper expansion with the initial support, and at the same time, an excessively loaded shield support causes a decrease in the working support of the section. Consequently, this situation leads to the fall of roof rocks, difficulties in moving the section and damage of the hydraulic legs of the canopy support. Difficulties in ensuring the stability of the excavation can intensify significantly when the geometrical form of the powered roof support structure does not provide active support of the roof over the entire length of the canopy.

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