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# CHOICE OF SUPPORT AND ROADWAY DRIVAGE IN HARD ROCK MINING

Summary. In Polish coal mining headings are driven at greater dept with the constant growth of their cross-sections. The average depth at which the Mining Construction Establishment performed the access operations reached 650 m in 1985. The approximate increase is 12 m per year. At great depth the growth of all types of pressures is accompanied by the occurrence of rock being less resistive to the water effect. In such conditions, tunnelling and maintenance of roadways brings forth technological and economic problems. In many cases floor upheaval started only a few meters behind the face and did not stop even after several dinting operations. Negative impact of floor rock extraction upon stability of neighbouring headings, especially near the shaft bottom, is observed. Application of arch support with the steel floor bar appeared as an effective method preventing the excessive floor upheaval. Therefore, a series of closed-profile arch supports of different strength has been designed. The developed selection principles base upon the evaluation of geotechnical parameters of rock, focusing especially on the loss of strength due to the water effect. Standard systems employing both roadheaders and blasting were developed. They may employ all known types of tunnelling machinery, both wheel and caterpillar based. Tunnelling methods in difficult mining and geological conditions are illustrated by examples of roadway drivage with the proposed closed-profile arch support reinforced by shotcrete.

## 1. INTRODUCTION

In Polish coal mining industry, access to new deposits is associated by the worsening mining and geological conditions. Access heading of larger cross-section are driven at higher depths; in rock of low geomechanical parameters and often not resistive to the water effect. Therefore, particular sections of roadways are subject to different rock pressure imposed upon the support., depending on the type of rock, however growing constantly along with the depth increase. It also appears more frequently that it is required to drive roadways in the conditions of tectonic disturbances as well as rockburst and otuburst hazard.

In such conditions obtaining satisfactory advance with minimum maintenance costs required a number of technological solutions, developed by the Mining Construction Establishment cooperating with the Research and Development Centre for Mine Construction "BUDOKOP" and the Central Mining Institute. The recent paper describes the solutions for the proper selection of support, preventing floor upheaval and ensuring the required drivage advance.

## 2. CHARACTERISTICS OF MINING AND GEOLOGICAL CONDITIONS OF OPENING OPERATIONS

### 2.1. Geological conditions

The majority of opening operations is performed in the Upper Silesian Coal Basin, being a triangular trough touching with its basis the Carpatian Mountains. Westernrand southern edges are characterized by the increasing fold distribances along with the outcrop of older series. Apart from folds, numerous disturbances of fault character are present throughout the region. Some of them, often several hundred meters wide, end consaining large water volumes create utmost hard conditions when driving through them by access headings. The strata are constituted not only by coal rock but also sandstone, mudstone and clays. For the support selection, geotechnical parameters of carbon rock for particular layers of similar lithological formation, were determined on the basis of statistical analysis, carried out for the depth of 1000 m. At present, the same parameters are being determined for strata 1000-2000 m deep. As different to the Upper Silesian Coal Basin where excavation goes deeper and deeper along with time, in Lublin Coal Basin operations were initiated already at great depth, i.e. below 900 m. In future the mining depth will increase. Carbon formations are composed here by the continuous series of clays and mudstone with occasional and uncontinuous layers of low grain sandstone. The majority of layers in which opening operations are being performed represents low strength parameters ($R_c$ = = 20-30 MPa) and low resistivity to the water effect (r = aprox. 0.5). It should be therefore considered that the original strength parameters of rock surrounding the headings will be lost due to the mine atmosphere effect. The calculated strata stability coefficient is characterized as:

$$\beta = \frac{k_o R_{cs}}{\varrho_o M 10^2} \qquad (1)$$

where:

$k_o$ - stress concentration coefficient,

$R_{cs}$ - rock compressive strength,

$\varrho_0$ - rock density,
M - depth.

The velue for the newly constructed mines of Lublin Coal Basin is twice lower when compared to the approximate values for the conditions of new mines in the Upper Silesian Coal Basin.

## 2.2. Mining conditions

In 1985 firms grouped in the Mine Construction Corporation constructed more than 3.5 km of shafts sunk from the surface, about 1.5 km of deepened and inter-level shafts, 315 km of roadways, including 225 km in rock as well as 1 million $m^3$ of chambers. 65% of headings were horizontal whereas the remaining 35% either dipped or raised. 90% of faces were driven in methane hazard conditions.

The average depth of opening operations reached 660 m in 1985 to increase by approximately 12 m a year. At several mines faces are driven at the depth of 1000 m.
It was long ago that mining construction firms had practically two types of support at their disposal. They were:

- open profile arch support of KS/KO-21 bars for roadways,
- brick lining for chambers.

It has been only during the last twenty years that the choice of support available was considerably widened. At present we employ a series of modern arch supports of 21-44 kg/m bars and a wide range of sheath supports. Closed-profile supports become also more sophisticated constructions providing better tunnelling performance.

Rock headings are driven traditionally by blasting whereas the majority of coal/rock headings employs roadheaders. Mechanization with the blasting technique used includes a side loader moving coal onto the scrapper conveyor or directly for the cars as well as shockrotary manual drills working from a prop or a drill jumbo. Car handling on the switching plates employs windlasses. In headings of larger cross-sections roof-suspended self-powered platforms as well as units for arch support setting are being commonly introduced. In the conditions of soaking floor a side loader is often replaced by two ŁZK-6P back loaders.

The most popular roadheader for rock/coal headings is AM 50 manufactured in Poland under Voest-Alpine licence. Purchase of the full-face shield for driving roadways in stoneis being considered.

Depending on the equipment and type of rock the advance per month ranged from 80 m with two back loaders and manual drilling to 200 m in faces equipped with a side loader and a drill jumbo and 300 m for coal/rock headings driven by roadheaders. At present, the average cross-section of roadways equals:

- 17.00 $m^2$ (in rock),
- 16.00 $m^2$ (in coal/rock).

The share of rock roadways of cross-section above 20 $m^2$ increases permanently. Removal of the heaved floor employs "Niwka" floor loader.

## 3. DIRECTIONS OF DEVELOPMENT

### 3.1. Principles of support selection

The increasing application of arch support, combined also with roof bolting and shotcrete, new types of steel profiles for arch support and consequently higher investment and maintenance costs made it necessary to develop principles of support selection appearing as a simple engineering procedure.

The method developed by the Research and Development Centre "BUDOKOP" bases upon calculation of the load imposed on the support and selection, on the basis of respective nomograms, of spacing of the arch support gases or arch support reinforced by shotcrete or bolts, or by both (4).

The load imposed on the support is determined through three parameters:

- approximate rock fimness - $\bar{z}_g$,
- depth - H,
- headings width at the support cross-section - $s_o$

where rock fracturing and soaking around the heading are expressed by the respective rock weakening coefficient k. The values of $q_o$ calculated for $\bar{z}_g$ = 2; 2.5; 3 and 4, H = 400-1100 m and $s_o$ = 3-10 m have been listed in respective nomograms (1,4).

The nomogram for $\bar{z}_g$ = 2 is presented on Fig. 1.

On the basis of theoretical and empirical investigations, strength of single gates was determined for different size and for sections of 21-44 kg/m weight. Three types of support-rock interaction were considered, i.e. for weak, stone packing, strong stone packing and mortar. The required gate spacing is read out from the corresponding nomograms presented in the paper (6).

Respective nomograms were prepared also for arch support reinforced with shotcrete and bolts (4).

### 3.2. Support construction

Till now maintenance of a heading where floor upheaval occurred, emploed dinting with the use of a floor loader.

With some types of rock even several dinting operation could not stop the heave. It was also observed that excavation of the rock has negative influence on neighbouring headings especially in the shaft bottom area.

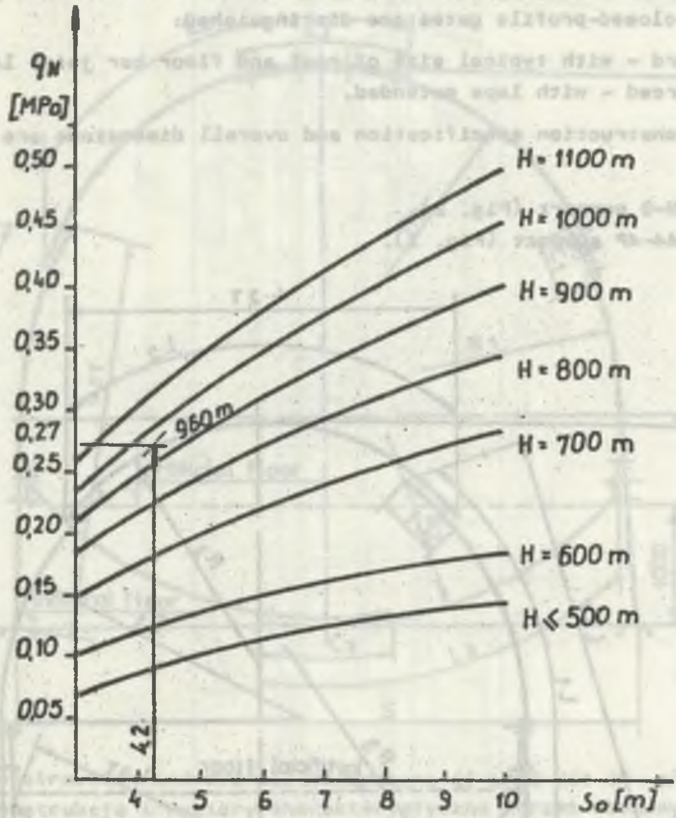


Fig. 1. Nomogram of characteristic load values $q_N$ for average rock firmness $\bar{z}_g = 2$

Rys. 1. Nomogram wartości obciążenia charakterystycznego $q_N$ dla średniej zwięzłości górotworu $z_g = 2$

In one of the mines excavatiion of large quantities of floor rock in the shaft bottom area resulted in destruction of the shaft lining above the level as well as destruction of the shaft bottom support. Under such circumstances closed-profile support has been successfully introduced. As direct construction of the support at face reduced considerably the advance, a series of closed-profile supports was developed being adapted for two-phase setting (7). Moreover, the performed underground tests indicated that despite significant destressing of floor rock some delays in setting the floor bar are not only possible but even recommended in certain conditions.

Gates of the closed-profile support incorporate usually standard roof arches, extended sidewall arches and floor arches. Couplings of roof arches with sidewall ones are typical yielding joints sheresa connections of floor bars with sidewall arches are square or articulated joints. Two types of closed-profile gates are distinguished:

standard - with typical size of roof and floor bar joint laps
reinforced - with laps extended.

Arch construction specification and overall dimensions are exemplified by:

- ŁPPZ-V29-S support (Fig. 2),
- ŁPPZw-V44-4P support (Fig. 3).

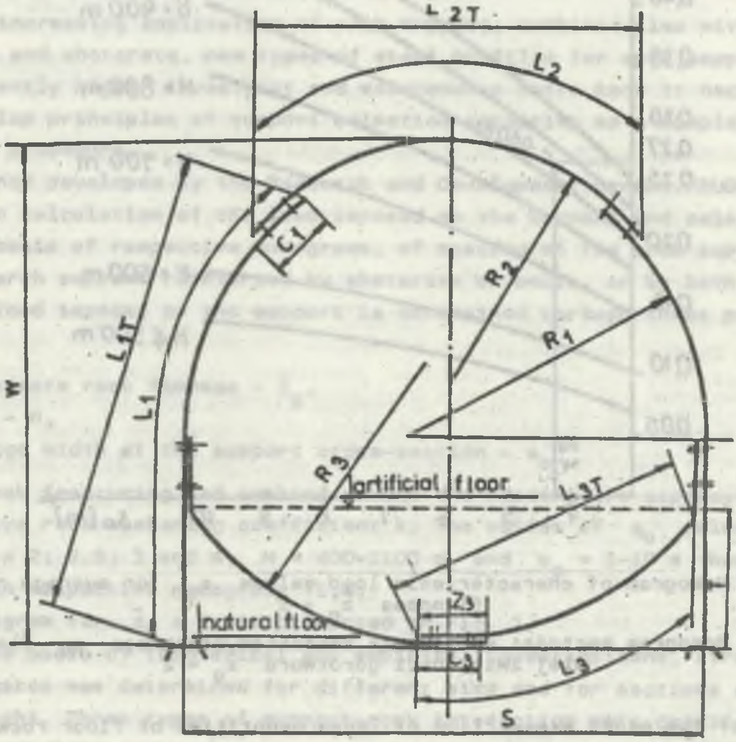


Fig. 2. Construction and overall dimensions of ŁPPZ-V29-S arch support
Rys. 2. Konstrukcja i wymiary charakterystyczne odrzwi obudowy ŁPPZ-V29-S

### 3.3. Roadway drivage technology with closed-profile support

Roadways with ŁPPZ support (heightend closed-profile yielding arches) are driven full face with flat floor employing standard mechanization systems; convertional or roadheaders. Directly at face open profile heightened gates are set. Floor bars are set without prior dinting, at approximate distance from the face, regardless the face operations being performed. Along with floor bars setting artificial floor of the heading is constructed by filling the floor space by the excavated material.

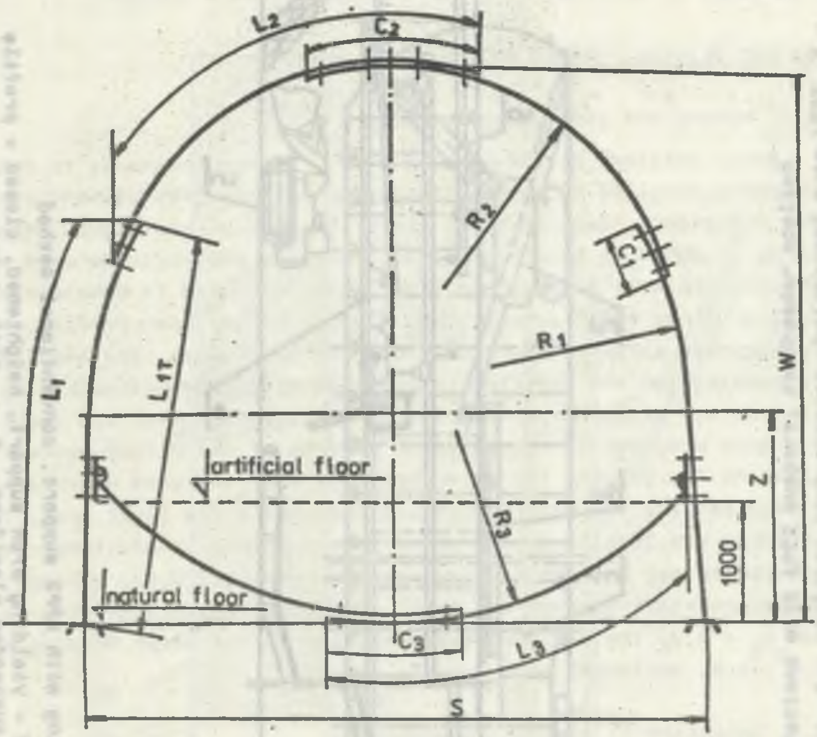


Fig. 3. Construction and overall dimensions of ŁPPZ-V44-4P arch support
Rys. 3. Konstrukcja i wymiary charakterystyczne odrzwi obudowy ŁPP-V44-4P

The tunnelling technology is illustrated by two examples:

- conventional method (Fig. 4),
- roadhearders employed (Fig. 5).

The presented examples of driving roadways with ŁPPZ heightened closed-profile arch support are significantly advantageous when compared to tunnelling with closed-profile support set at face in one phase. It enables parallel performance of face operations employing typical machinery moving on the natural flat floor as well as setting floor bars and filling the floor with the excavated material. Therefore, the obtained advance is only slightly lower than in case of the same machinery and on open profile support. When closed-profile support was set at face during one phase, advance decreased nearly by 50%, wheres one of the presented tunnelling methods with ŁPPZ support resulted in advance decrease not higher than 10%. The cost of 1 m of heading driven with ŁPPZ support is 30-40% higher than tunelling with open-profile support.

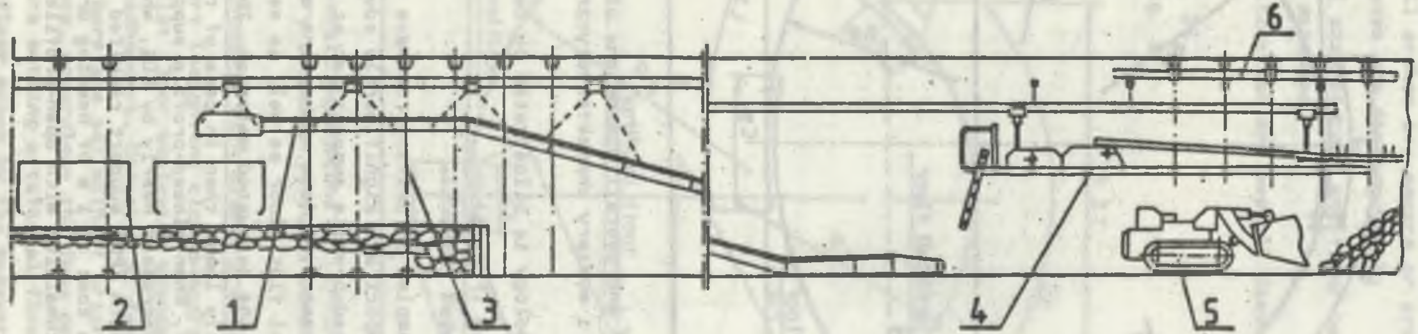


Fig. 4. Mechanization of tunneling with ŁPPZ support, conventional method
1 - roof suspended belt conveyor, 2 - mine car, 3 - yielding arch support, heightened, closed - profile type ŁPPZ, 4 - self - powered suspended plastform, 5 - rail jointe

Rys. 4. Schemat układu mechanizacyjnego do drężenia wyrobisk korytarzowych w obudowie ŁPPZ metodą konwencjonalną

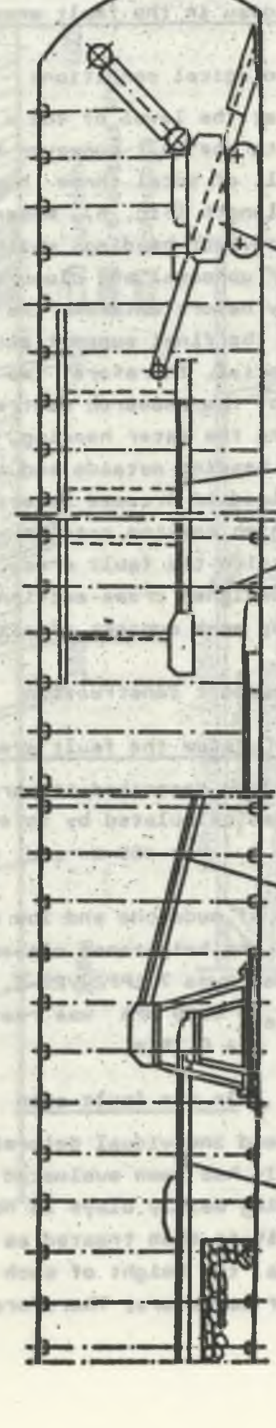


Fig. 5. Mechanization of tunneling operations with ŁPPZ support, roadheader applied
1 - belt conveyor, 2 - floor based scrapper conveyor, 3 - yielding arch support, heightened type ŁPPZ, 4 - roof suspended scrapper conveyor, 5 - roadheader

Rys. 5. Schemat układu mechanizacyjnego do drążenia wyrobisk korytarzowych w obudowie ŁPPZ metodą kombajnową

## 4. EXAMPLES OF APPLICATION OF ŁPPZ CLOSED-PROFILE SUPPORT

### 4.1. For driving roadway in the fault area

#### 4.1.1. Mining and geological conditions

In "Lenin" colliery at the level of 465 m it was necessary to drive a water heading parallel to the belt conveyor heading. The heading was to pass the "Księżęcy" fault of total throw $h = 420$ m and highly watered fault area of 200 m in length (Fig. 6). Numerous difficulties were met when driving the belt conveyor heading, which resulted in considerable delays, e.g. large floor upheaval and closure of the open-profile arch support occurred already before entering the fault area. The heading had to be reconstructed and the final support setting consumed much time and large quantities of material. Therefore, two technological and technical projects were provided by the research centres of the Mine Construction Establishment for driving the water heading. They included guidelines to follow when deiving the heading outside and inside the fault area. The water heading was localized in Orzesze layers mainly in mudstone. Mudstone is characterized by high soaking rate ($r$ = approx. 0.6). Avarage rock firmness at sections outside the fault area, determined according to (1) equaled $\bar{z}_g = 2.8$. The designed cross-section of the water heading was $F = 10$ m$^2$, i.e. employing arch support of size 7.

#### 4.1.2. Selection of support construction

Outside the fault area

Employing the methodology described in paragraph 3.1 the value of load imposed on the support was calculated by interpolation of nomogram values for $\bar{z}_g = 2.5$ and $\bar{z}_g = 3$, $H = 465$ m and $s_o = 4.35$ m, $q_o = k$, $q_N = 0.08$ MPa.
Considering low strength of mudstone and low resistivity to water the adopted construction was the heightened closed-profile yielding arch support made of V29 sections: type 7 ŁPPZ-V29-S.
The gates spacing for $q_o = 0.08$ MPa was read out from nomogram for weak, hand laid packing $d = 0.75$ m.

In the fault area

Guidelines (4) recommend individual determination of the calculated load in the fault zone. It has been evaluated that in a highly watered fault zone, rock containing mainly clays is not firm enough to transmit the original pressures; it is then treated as a loose rock. It is estimated that in fault zones, the height of such rock deposit above a heading may reach a dozen or so meters. Therefore, $q_o = 0.5$ MPa was adop-

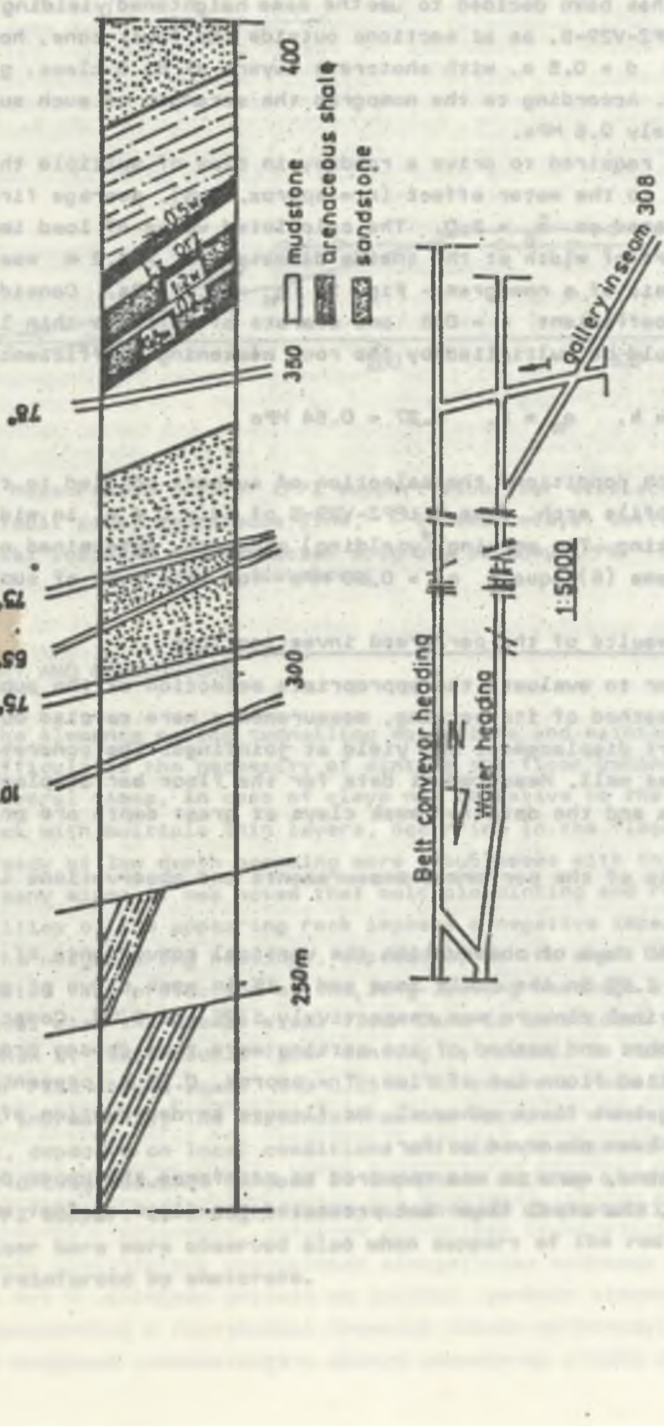


Fig. 6. Layout and geological cross-cut of the water heading at 465 m level in "Lenin" colliery

Rys. 6. Plan sytuacyjny i przekrój geologiczny przekopu wodnego na poz. 465 m KWK Lenin ted for the calculations. Such high load cannot be borne by a yielding arch support, even when providing perfect cooperation with rock. Therefore, it has been decided to use the same heightened yielding arch support type 7 ŁPPZ-V29-S, as at sections outside the fault zone, however with the width d = 0.5 m, with shotcrete layers of B1 0 class, g = 0.2 m thickness. According to the nomogram the strength of such support equals aproximately 0.6 MPa.

It was required to drive a roadway in clay of multiple thin layers not resistive to the water effect (r = approx. 0.5). Average firmness of rock was estimated as $\bar{z}_g$ = 2.0. The calculated value of load imposed upon the support of width at the inside diameter $s_o$ = 4.2 m was determined on the basis of a nomogram - Fig. 1; $q_N$ = 0.27 MPa. Considering the soaking coefficient r = 0.5 and starata of multiple thin layers the value should be multiplied by the rock weakening coefficient k = 2.

$$q_o = k, \quad q_N = 2, \quad 0.27 = 0.54 \text{ MPa}$$

For such conditions the selection of support pointed to the yielding closed-profile arch, type 7 ŁPPZ-V29-S of d = 0.4 m in width solid concrete packing. The working (yielding) strength, determined on the basis of nomograms (6) equals $q_z$ = 0.60 MPa for this type of support.

### 4.3. Results of the performed investigations

In order to evaluate the appropriate selection of the support construction and method of its setting, measurements were carcied out to indicate the support displacement and yield at jointings. The concrete surface was observed as well. Measurement data for the floor bar displacement in the fault zone and the data for weak clays at great depth are presented on Fig. 7.

Analysis of the performed measurements and observations indicated that:

- after 360 days of observation the vertical convergence of the heading equaled 1.2% in the fault zone and 3.1% in weak clays at great depth; the vertical closure was respectively 1.2% and 0.9%. Construction of the support and method of its setting were thus chosen properly;
- the applied floor bar of rise T = approx. 0.25 m presents the headings against floor upheaval. No flexure or destruction of the floor bar has been observed so far;
- at sections, were it was required to reinforce the upper part of the support, the steel floor bar protected the floor against upheaval.

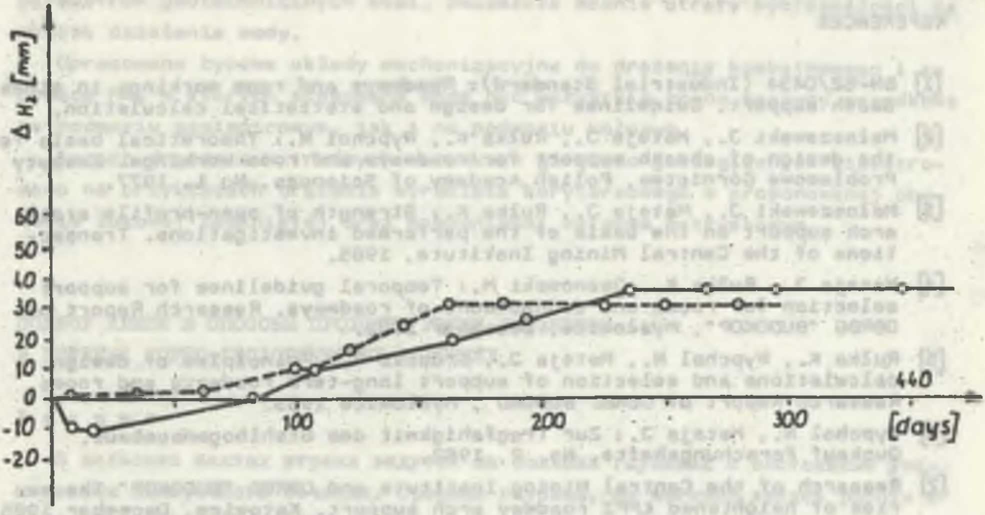


Fig. 7. Measurement data of ŁPPZ support floor bar displacement - in the fault zone: continuous line, - in weak clays: dotted line

Rys. 7. Wyniki pomiarów przemieszczeń spągnicy obudowy ŁPPZ w strefie uskokowej

## 5. SUMMARY AND CONCLUSIONS

One of the elements making tunnelling operations and maintenance of roadways difficult is the necessity of dinting the floor behind the face, often for several times. In case of clays not resistive to the water effect, or rock with multiple thin layers, occurring in the floor, upheaval appears already at low depth becoming more troublesome with the dept increase. In many mines it was noted that multiple dinting and removal of large quantities of the appearing rock imposes a negative impact on stability of the neighbouring headings, especially at the shaft bottom. It is estimated that protection of the long-lasting headings against floor upheaval with the use of steel floor bars is beneficial and well justified when at least double floor dinting is needed. In multi layer rock the bar rise should equal $T \geqslant 0.25$ S. In coherent rock it may be required to increase it. The distance from the face, at which the floor bar was set, depended on local conditions and did not exceed 50 m. Decrease of drivege advance in case of two-phase setting of the closed--profile ŁPPZ support is unsignificant. Advantages of protecting floor with the floor bars were observed also when support of the roof and sidewalls were reinforced by shotcrete.

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Wpłynęło do Redakcji we wrześniu 1987 r.

## DOBÓR OBUDOWY I SPOSOBY DRĄŻENIA WYROBISK KORYTARZOWYCH W TRUDNYCH WARUNKACH GÓRNICZO-GEOLOGICZNYCH

### S t r e s z c z e n i e


Wyrobiska udostępniające drążone są w krajowym górnictwie węglowym na coraz większych głębokościach, a ich przekrój poprzeczny stale rośnie. Średnia głębokość, na której Zakłady Robót Górniczych prowadziły roboty udostępniające, wynosiła w 1985 roku w polskim górnictwie węglowym 650 m. Rośnie ona średnio o ok. 12 m na rok. Na dużych głębokościach obok notowanego wzrostu wszechstronnych ciśnień, pokładom węgla towarzyszą skały coraz mniej odporne na działanie wody. W tych warunkach, zarówno drążenie wyrobisk korytarzowych, jak i ich utrzymanie stanowią problemy techniczne i ekonomiczne. W wielu przypadkach już kilka metrów za przodkiem zaczyna się zjawisko wypiętrzania spągu, które nawet po kilkakrotnym spągowaniu nie ustaje. Obserwuje się niekorzystny wpływ wybierania skał spągowych na stateczność sąsiednich wyrobisk, zwłaszcza w obrębie podszybia. Skutecznym sposobem zapobiegania nadmiernemu wypiętrzeniu spągu okazało się zastosowanie obudowy łukowej ze stalową spągnicą. W tym celu zaprojektowano typoszereg obudów łukowych zamkniętych o zróżnicowanej nośności. Dla ich doboru opracowano zasady projektowania, bazujące na ocenie

parametrów geotechnicznych skał, zwłaszcza ocenie utraty wytrzymałości na skutek działania wody.

Opracowano typowe układy mechanizacyjne do drążenia kombajnowego i za pomocą MW, w których stosowane mogą być wszystkie znane maszyny przodkowe na podwoziu gąsienicowym, jak i na podwoziu kołowym.

Sposób drążenia w trudnych warunkach górniczo-geologicznych zilustrowano na przykładach drążenia wyrobiska korytarzowego w proponowanej obudowie łukowej zamkniętej oraz wzmocnionej betonem natryskowym.

## ПОДБОР КРЕПИ И СПОСОБЫ ПРОХОДКИ УЗКИХ ВЫРАБОТОК В ТРУДНЫХ ГОРНО-ГЕОЛОГИЧЕСКИХ УСЛОВИЯХ

Р е з ю м е

В польских шахтах штреки ведутся на больших глубинах с постоянным увеличением поперечного сечения. Средняя глубина, на которой велись работы в 1985 году, составляла 650 метров. Годовый прирост глубины в среднем 12 метров. На большой глубине увеличение давления сопутствуюг появление скал менее устойчивых на воздействие воды.

При проходке тоннелей и дорог в таких условиях возникают технологические и экономические проблемы. Часто поднятие кровли начиналось в нескольких метрах от забоя и не останавливалось даже после нескольких подрывок.

Замечено отрицательное влияние выработки на стабильность соседних забоев, особенно вблизи околоствольного двора. В качестве эффективного метода предохранения кровли перед поднятием применяются арочные подборы со стальным стержнем. Поэтому запроектирована серия арочных подпор различной силы с замкнутым профилем.

Селекция основ опирается на оценке геотехнических параметров скалы, особенно концентрируяоь на потери силы под действием воды. Развиты стандартные системы, использующие все известные типы устройств для проходки тоннелей, как колёсные, так и гусеничные. Методы проходки тоннелей в трудиых горных и геологических условиях представлены на примере арочных выработок с предложенной поддерживающей аркой с замкнутым профилем, усиленным торкрет-бетоном.