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Roadways development and monitoring within deep coal mines in the Czech Republic

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ROADWAYS DEVELOPMENT AND MONITORING WITHIN DEEP COAL MINES IN THE CZECH REPUBLIC

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ABSTRACT: Use of the system of dual-use of gateroads represents a significant change in the hitherto preferred method of addressing of mining works development. The entire system is based on the principle of reuse of one gateroad during the process of mining of the pair of neighbouring mining panels. The basic condition for its possible application is the stability of the supporting reinforcement of the gateroad so as for it to be able to withstand the additional loads originating in conducting longwalls or other expected supplementary loads to ensure the stability of the mine working throughout its required service life. Sufficient stability of these workings is ensured by the high anchoring method. It is a supporting system of long, large-area, possibly atypical mine workings, in which the elements of supporting reinforcement are embedded in solid layers of higher overburden of the supported mine working. The following paper presents the hitherto results of the process of verification of suitability of deployment of the high anchoring method for the aforementioned purpose, which was carried out in situ in the gateroad 063 5348 of Paskov Mine.

INTRODUCTION

Exploitation of black coal at ever greater depths means a shift in both the geological and geomechanical conditions, which places great demands on the design, realization and load-bearing capacity of the supported mine workings. Another factor which leads to the need for an increase of the bearing capacity of the reinforcement supports is that gateroads are often used twice. If a mine working is to fulfil its purpose for longer, the adverse effects of stress and strain deformation effects on the rock mass can be limited by means of rod bolts and flexible anchors, or by means of an increase of reinforcement support load bearing capacity through stranded anchors in combination with steel arch supports.

The essence of high anchoring technology consists in the use of materials with the necessary strength characteristics, capable of transmitting high loads in the body of the anchors, both in the axial and radial direction, with concurrent sufficiently solid and resistant link between the anchor, the resin and the rock. High anchoring performs correctly only in well-driven mine workings, with properly secured over-laminations behind the steel arch supports. High anchoring consists of a steel arch plane with a reinforced hole, stranded anchor and a sealant, by means of which the anchor is clamped in the rock mass.

BASIC CHARACTERISTICS OF STRANDED ANCHORS

Anchors applied in the rock mass govern the behaviour of rocks and their layers based on the principles of reinforcement. Installing stranded anchors bonded in the bore allows for better reinforcement of rock structures and avoids their possible stratification, which significantly influences the stability of immediate overburden and bedrock of underground and mine workings (elimination of the rate of convergence) (Souček et al., 2012, Kukutsch et al., 2013).
The extent of reinforcement of the rock layers may exceed due to the length of the used anchors several times the height of underground or mine working, roadway, and longwall face end.

The most common use in practice are for:

- reinforcing mine roadways and longwall face ends;
- reinforcement of outsized underground or mine workings - crosses, forks, branches and chambers, etc.
- reinforcement of underground and mine workings with long service life,
- reinforcement of long mine workings for dual-use for adjacent longwall mining,
- reinforced securing of roadways or mine workings with an increased tension, eg roadways in the face-gate contact, in front of the advancing longwall.

**PRINCIPLE OF PLANNING AND DESIGNING OF GATERoadS FOR DUAL-USE**

Dual-use gateroads represents a significant change in the existing conventional solutions to development and mining works not only within one seam, but generally the whole block. This implies the need to address the selection of gateroads for dual-use at the time of preparation of the plan of opening, development and extraction of a coal seam or block. Compliance with the temporal requirements for development and extraction using the dual-use gateroad method is of quite an extraordinary importance.

The driveage of gateroads designed for dual-use must be based on a technological project according to these main principles (Technical Standard No. 1, 2009):

- When selecting gateroads suitable for dual-use it is necessary to take into account geological and mining conditions in which the gateroad will be driven. The evaluation must include assessment of the climatic conditions in the given area and a detailed evaluation of the degree of risk of spontaneous combustion of the seam in question.
- Gateroads, which are intended for dual-use, must always be at the time driveage be reinforced by combined supports.

When designing gateroads for dual-use it is necessary to consider t with the fact that after crossing of the coal face of the first longwall it is necessary to immediately proceed to the construction of a protected rib along the gateroad. After coal extraction of the seam the rib becomes the essential protective element to ensure the stability, shape and profile of the mine working. Protective rib preferably best performs its function if it is built as close as possible to the rib of the working and creates a solid and stable unit.

The protective rib is usually of a width, using stacks of hardwood or floating of fast-curing materials, equaling seven tenths of the mined seam thickness. If the extracted seam thickness is less than 1.5 m, then the minimum width of a rib is 1 m. The number of steel arch settings and the density of props building in the area of rib is specified by the technological procedure for the comencement or starting up of the first longwall.

**GUIDELINES FOR THE SELECTION OF LONGWALLS AND GATERoadS INTENDED FOR DUAL-USE**

Selection of gateroads for dual-use is based on the layout of longwall panels in the given seam and / or its part (block, field). Gateroads for dual-use are those that are separated by neighbouring longwall panels. The gate of the previously extracted panel is the mining gate and the gate of the subsequently mined panel is the return gate. In the case of more consecutively mined adjacent longwall panels the gateroads designed for dual-use can create a whole system...
in the seam / part of the seam. It is necessary for extraction of adjacent blocks, between which there is a gateroad intended for dual-use to be mined as much consecutively as possible. Large time lag between the extraction of the neighbouring blocks eliminates the positive effect of the extraction technology with dual-use of gateroads, since the relevant gateroad designed for dual-use is exposed for too long to the effects of rock mass pressures.

Dual-use corridors can be realized only in suitable geological conditions, which are given by thickness and gradient of the coal seam, the quality of the overlying and underlying rocks, and geomechanical properties of the rock mass. Under suitable conditions it is considered (Technical Standard No.4, 2011):

- seam thickness of up to 2.5 m, in a very favourable geological and geomechanical conditions up to 3 m,
- seam incline the minimum possible, thus the seam flat deposition (up to 22°), greater incline means worse conditions for the application of this technology,
- seam overlay preferably solid, not prone to multiple break-outs, suitable for application in the rockbolt supporting system in the gateroad in question,
- seam underlay formed by solid rocks so as to avoid floor lifting in the gateroad in question,
- low tectonic fracturing of the relevant part of the rock mass, in order to be able to ensure the stability of the relevant gateroads with available resources, in the needed sufficiently large cross-sections (up to about 30 m²),
- strain fields such that the gateroads intended for dual-use are not subjected during their necessary life by extremely high primary especially and especially induced strains from mine workings situated in the overlay, the seam itself in the underlay (residual pillars of any kind, edges of back ends and others),
- hydrogeological conditions - without or with little water content in the rock mass in the seam overlay,
- risk of anomalous phenomena in any case means a complication, however, does not exclude the use of dual-use gateroads.

Due to the limitations of this technology on the top area of the deposited seam it is necessary to consider in particular the risk of rock bursts and the risk of outbursts.

**MONITORING OF THE GATEROAD 063 5348**

Gateroad number 063 5348 was located in the seam 063 (17b) at Paskov Mine, which is a mine without the danger of rock bursts. This seam is included in the second coal and gas outburst risk class. The seam incline is variable from 18 to 25 degrees. The underlay of the seam consists predominantly of siltstone, and the overlay in the section of 830 to 690 m contained siltstone with fine sand and thin sandstone lamination, 690-490 m transitions into sandstone, 490-390 m siltstone with sandstone lamination and the section 390-330 m contained siltstone.

Mining of the longwall No. 063 607 (Fig. 1) was launched at the starting stationing of 825 m in the gateroad No. 063 5348. Average mined thickness of the longwall was 214 cm, the length of the face was 169 m and the directional length of the longwall was approximately 480 m. Average daily advance of the face was around three meters.
Mechanical extensometers

Installation of 10 units of checking extensometers, type TTW07S (Fig. 2) with a length of 12 m was performed in boreholes with a length of 12.5 m and a diameter of 35 mm in the gateroad No. 063 5348 with a spacing of 50 m in the stationing 837 m, 784 m, 737 m, 687 m, 637 m, 583 m, 537 m, 487 m, 433 m a 383 m (labelled E1 to E10).

The TTW07S extensometer is a three-level design type. The height of the anchor "A" is 4000 mm, the height of the anchor "B" is 8000 mm and the height of the anchor "C" is 12000 mm above the roof of the mine working.

Monitoring of the extensometers consisted in control of the color scale or its part located under the roof outside the reference scale of the extensometer and accurate reading on the scales "A" and "B", "C" in millimetres was performed by the employees in weekly intervals throughout the entire period of 063 607 longwall mining.
The records of measurements on scale "A" and "B" and "C" of mechanical extensometers clearly imply that the most extensive displacement of the overlying rock occurred in the course of transition of the longwall in the section of about 100 m from the initial breakthrough when in the case of the scale "A" the value of displacement ranged up to 75 mm (full retraction of scale "A"). The most noticeable displacement was recorded in extensometers No. 1, 2 and 3. The remaining extensometers registered displacement in the range from 5 to 25 mm.

Almost a similar nature and trend of the development of the measured results of displacement of the overlying rock can be seen also in "B" scales. The highest increases of the displacement values were recorded in the extensometers No. 1, 2, 3, which were showing values increased up to 75 mm (full retraction of scale "B"). The value of displacement of the overlying rock in the remaining extensometer with "B" scales did not exceed 40 mm.

The measured results imply that the overall value of displacement (A+B+C) exceeded the value of 225 mm in two extensometers. The overall value of displacement in the remaining extensometers is not so significant, however the damage of several extensometers complicates the interpretation of the rock mass behaviour.

We expect that the increases at the extensometers E1, E2 and E3 are caused by the influence of the horizontal stresses behind the advancing face, which manifest from the stationing of 720 m in a significant deformation of the mine working.

**Dynamometers**

Three measuring stations were established in the gateroad no. 063 5348, where two dynamometers were installed to monitor the load of the stranded anchors in mutual distance of 2 m.

Dynamometer by Sisgeo, L2M0 series, model designation 0L2M0705000 allows manual readings of values up to 500 kN. Dynamometers were installed in the central part of the roof arch of the steel arch support (Fig. 3).

Location of stations each with a pair of dynamometers was at the time prior to mining of the longwall No. 063 607 at stationing 550 m (marking of dynamometers D6, D5), 630 m (D4, D3), 690 m (D2, D1). During the transition of the face through the measuring station in the 690 m stationing the dynamometers D1 and D2 were damaged. Based on this fact an additional dynamometer was installed in the 424 m stationing (D7).
Dynamometer readout was performed in weekly intervals. With regard to the increase in values just before the approaching face, it was decided to readout values in each shift, i.e., ideally 4 times a day.

During longwall mining, the increase of values was observed only in the immediate foreground of the longwall (located within the influence of additional stress from the edge of the longwall face). However, in the field behind the longwall the pressure effects of the overlay resulted in the change of the values on the installed dynamometers, which show an increasing trend with the increasing distance of the longwall. The maximum value of additional load was 220 kN (i.e. 22 tons), minimum value was 0 kN. The increase of values in dynamometers D3 and D4 depending on the advance of the coalface during two months is shown in figure 4.

![Dynamometric load profile](image)

**Figure 4: Development of load of dynamometers D3, D4**

**Vertical and horizontal convergence**

In places of the installed dynamometers were fitted with points for measuring vertical and horizontal convergence of the mine working. The measuring points for vertical and horizontal convergence in the gateroad No. 063 5348 were located in the monitoring places on hydraulic dynamometers, i.e. in the stationing 550 m, 630 m, 690 m.

Measurement of vertical and horizontal convergence was performed at weekly intervals.

In terms of stability of the gateroad No. 063 5348 the development of the measured values of vertical and horizontal convergence before the longwall was of other nature than in the places where convergence measurement does not take place, but the deformation of the mine working profile was very pronounced. While the convergence and slippages of reinforcement steel arches at the connecting stirrups of the monitored gateroad ahead of the face have been showing nearly identical results (reduced heights and widths: 150 mm, 80 mm, 15 mm slippages), maximum values of convergence on the unmeasured sites (area of extensometers 1-3, where there has been a maximum displacement) several times exceeding the values from the convergence profiles. In the section behind the face (stations 720-825 m) the devices
registered a decrease of the width and height of the profile of the mine working by 100 cm, respectively up to 200 cm (stationing 825 m, height 2.8 m, width 3.4 m - original profile height 3.8 m, width 5.36 m). The areas ahead of the longwall face and behind it were also subject of continuous floor brushing.

CONCLUSION

The article evaluates in a limited extent the partial results of monitoring and convergence of the gateroad No. 063 5348 of Paskov Mine. The hitherto results show that the issue of gateroads for dual-use in combination with high anchoring needs to be addressed, because it was confirmed that the high anchoring performs its function well only in a well driven mine working without overbreaks. The graph in figure 4 shows that the increase in load of the monitored anchor occurs when the monitored anchors get behind the edge of the longwall face. It is apparent from the observation of the mine working that the floor along with the steel arch supports are lifted before the advancing face, which results in a release of the installed stranded anchors. Judging according to the provisional results of the first approximation, we can state that the positive effect on the function of high anchoring and combined reinforcing systems could be achieved by highly pre-tensioned stranded anchors (at least to a value of 150 kN), which were a part of another experiment at Mine Paskov in the seam 080, in the gateroad No. 080 5253.

The most significant displacement of the overburden and the highest convergence of the profile of the gateroad No. 063 5348 were recorded in the area of extensometers E1, E2 and E3, which were caused by the influence of horizontal stress behind the advancing face, and which manifest from stationing of 720 m in a significant deformation of the mine working, and adverse geological conditions in the area (incidence of tectonics). The influence of geological conditions will continue to be the subject of further investigation based on the development of the monitored parameters. Objective evaluation can be made only by comparing the RQD parameter from the boreholes drilled ahead of the advancing face and boreholes performed in the same stations after passing of the longwall face.

The monitoring results presented in this paper demonstrate that the pressure conditions in the gateroad no. 063 5348 reflect both the deformation of the mine working behind the face, as well as the increase of the values on the installed extensometers and dynamometers, but only in the immediate vicinity of the face. We have to admit that pitfalls of the monitoring carried out consist in the fact that it is not always possible to combine operation and observation, so the extensometers are subject to damage (release, tearing of indicators), rebuilding of SA reinforcement with the identified convergence marks etc.

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