Protection of mine workings using compliant pillars

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Abstract. In this article, the authors consider the way of defining the compliance for different ways of securing excavation workings: fastening the mine workings by the combined roof bolting, including rope bolts of L = 6m, and barring the mine workings, using a yielding frame support of KPS type.

1. Introduction

During the period of the mine "Obukhovskaya" operation, the depth of mine workings has reached 744 m. The mine working is developing layer K₂ of brand (A), which by horizon -500 is classified as dangerous in rock bumps. The development system applied is as follows: the usage of long poles along strike with the reuse of excavation workings. With the increase of the depth of mine workings (transition to horizon -500), when developing extraction columns, the applied protection methods of excavation drifts (two rows of BDB with battery stulls) do not provide their maintenance-free condition before reuse. And the increased deficiency level of workings greatly complicates the mining, requires full or partial retimbering and construction of additional mounting ahead of the lava, which in its turn, leads to long downtime of the lava, reducing the load on the stope. On this basis, there is a necessity in transition to a single use of mine workings, serving the stope.

In this regard, there is the necessity of leaving interstratific pillars, which on rockburst-hazardous seams is the main source of rock bursts manifestation. Rockburst of such pillars can be completely neutralized by setting only artificial yield, because anthracite is fragile. The conducted analysis of papers [1-10] convincingly demonstrates that one of the promising directions on reduction of the harmful effects of rock pressure at great depths is the management and maintenance of the roof in clearing mines, as well as protection of preparatory workings, with the help of yielding pillars. However, in this work the flexibility is set "naturally", i.e. knowingly the pillars that are smaller in sizes than the calculated ones are accepted so that they are subsequently destroyed under the action of rock pressure.

Such method has several disadvantages, that is, it is almost impossible to manage the set yield using it. At that, it is unknown what should be its value, how it can be achieved and, most important, it is unknown how it will change the stability of the excavations, protected by the yielding pillars. In addition, in protection workings with the help of compliant pillar, it is very important that their size does not exceed the design because deviations in the direction of increasing the size of the rear sight will probably result in appearance of compression zones in the latter. At that, it is unknown how this...
will affect the sustainability of protected production and what are the conditions of its formation for various power reservoirs, width of the pillars and methods of defining compliance.

2. Materials and methods
In this regard, the authors have made an analysis of the registration and use of yielding pillars. The solution to this problem is presented in [1], where the method of calculation of the parameters of the yielding pillars is given. Currently, the most effective way of setting an artificial yielding coal pillars is their drilling by parallel wells, located at such distance from each other that allows the pillars between wells (jumpers) under the action of load to become broken. As studies, given in [2], have shown, the anthracite seams have virtually no long-term strength. Therefore, for this coal this method is unacceptable for determining the parameters of the pliable pillars by using the values of strength for a specified period of time in the calculations, because it practically will not differ from the relatively instantaneous one. In this article, the authors consider the most effective option of the set yielding for two different methods of attachment of excavation workings: when fixing workings by the combined roof bolting, including rope bolts of \( L = 6 \) m, and barring the excavations by the yielding frame lining (KPS). For the anthracite seams, the calculation of the yielding pillar is offered in the following sequence. The following is determined:

1. the sizes of the "hard" pillar;
2. the value of the predetermined yielding;
3. the diameter of the wells depending on the specified yielding value;
4. the number and density of drilled wells.

The sizes of the "hard" pillar are determined depending on the depth of the work, the purpose of the pillar, the compression material strength in, the ratio of the geometric dimensions (height and width of pillars) in the nomogram (figure 1), presented in [2].

![Figure 1. Nomogram of dependence of "hard" pillar sizes](image)

3. The study of the problem
Calculation of compliance of destructible inter-borehole pillars (the definition of the specified compliance) can be performed according to the scheme shown in Figure 1. Let the borehole diameter be \( D \) and the distance between the holes in the middle section of the well – \( d \).
Then the amount of space ABCE between average vertical cross-sections of two adjacent wells will be per unit of the well length:

\[ V_v = D(D+d). \tag{1} \]

The well volume per unit length will be equal to:

\[ V_{skv} = 0.785D^2. \tag{2} \]

Then the amount of coal in the inter-borehole pillar with round walls will be equal to:

\[ V_c = V_v - V_{skv}. \tag{3} \]

or

\[ V_c = D(0.215D+d). \tag{4} \]

The share of coal in the pillar per length unit relative to the amount of space, produced by drilling wells, will be:

\[ C_c = \frac{0.215D+d}{D+d}. \tag{5} \]

As a result of materials processing of extensive field studies in the anthracite mines of East Donbass, the formula for calculating the relative deformation of the material of the destroyed pillar has been obtained, which has the following form:

\[ \varepsilon_c = 0.90 - 1.3C_c, \tag{6} \]

where \( \varepsilon_c \) – the relative material compression of the destroyed inter-borehole pillars;

\( C_c \) – the proportion of the pillars left between the holes, equal to the ratio of the area of inter-borehole pillars to the total area of the discharge zone; 0.9 and 1.3 – empirical coefficients.

For determination of the compression value of the destroyed pillar, one should determine value \( C_c \) and substitute its magnitude in expression (6).

The determination of the necessary yielding of the pillar (the compression value of the destroyed pillar) is made, proceeding from the condition of joint operation of the mine working lining and the security pillar. That is, the yielding of the pillar DU is set, assuming it to be approximately equal to the
compliance value of the lining. And then, by the value of set compliance and the schedule, presented in Figure 3, the required diameter of wells and distances between wells (the density of wells drilling) are defined.

![Graph showing the dependence of pillar yielding on the distance between well walls and the diameter of the borehole.](image)

**Pillar yielding, U, mm**

**Figure 3.** The dependence of the yielding of the pillar on the operating conditions of the lining

4. **Conclusion**

The specified yielding for barring the mine working with roof bolting, including the rope bolts of L=6 m, having the yielding of 80 mm, was determined. The average amount of space in the pillar section, drilled out by wells, equal to their diameter, is:

$$V_v = D(D + d).$$  \hspace{1cm} (7)

The middle section of the element of the developed space between the two wells is:

$$S_v = D + d.$$  \hspace{1cm} (8)

The middle section of the pillar (jumper between the holes) is:

$$S_c = \frac{V_v}{D} = 0.215D + d.$$  \hspace{1cm} (9)

Then the share of coal in the inter-borehole pillar can be defined as follows:

$$C_c = \frac{S_c}{S_v} = \frac{0.215D + d}{D + d}.$$  \hspace{1cm} (10)

Accepting that \(D=0.4; \ d=0.2\) m, one will get:

$$C_c = \frac{0.215 \cdot 0.4 + 0.2}{0.4 + 0.2} = 0.47$$

which is the share of the coal left in the inter-borehole pillars.
Substituting $C_c = 0.47$ in expression (6), one will obtain the relative deformation of the destroyed coal in the inter-borehole jumpers:

$$\varepsilon_c = 0.90 - 1.3 \quad C_c = 0.9 - 1.3 \cdot 0.47 \approx 0.29$$

The value of 0.29 is a relative compression of the material of the destroyed pillar. In line with this, the absolute compression of the material of the pillar (yielding) will be:

$$\Delta U = \varepsilon_c D = 0.29 \cdot 0.4 \approx 0.12 \text{ m.}$$

Thus, the ductility of the drillable pillar in this example is about 20% of the diameter of the wells. When defining a predetermined flexibility for barring with the yielding frame support (KPS) having the yielding up to 300 mm, the yielding of the pillar will be:

Accepting that $D = 0.7; \ d = 0.2 \text{ m}$, one will get:

$$C_c = \frac{0.215 \cdot 0.7 + 0.2}{0.7 + 0.2} = 0.39$$

– the share of coal, left in the inter-borehole pillars.

Substituting $C_c = 0.39$ in expression (6), one will obtain the relative deformation of the destroyed coal in inter-borehole jumpers:

$$\varepsilon_c = 0.90 - 1.3 \quad C_c = 0.9 - 1.3 \cdot 0.39 = 0.39$$

Value 0.39 is a relative compression of the material of the destroyed pillar. In line with this, the absolute compression of the material of the pillar (yielding) will be $\Delta U = \varepsilon_c D = 0.39 \cdot 0.7 = 0.27 \text{ m.}$

Thus, when setting the artificial yielding for the pillar by drilling it with wells, its original load-carrying ability decreases proportionally to the decrease of its area.

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