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ANALYSIS OF THE METHODS OF CALCULATING THE MAIN ROOF-CAVING INCREMENT IN MINING SHALLOW COAL SEAMS WITH LONG BREAKING FACES

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ABSTRACT

The study was aimed at choosing and substantiating efficient methods of calculating main roof-caving increments during mining of shallow coal seams with long breaking faces. For the conditions of the Vorkuta coal deposit in the Pechora coal basin, Russia, actual main roof-caving increments and calculated values obtained with the use of the methods used in the mines have been comparatively analyzed. The applied methods of calculating roof-caving increments have been analyzed, and the reasons for the discrepancy between the actual and calculated values of the roof-caving increments have been shown. The significant influence of breaking face advancing rate on the roof-caving increment has been shown. Recommendations have been given for the use of this method, with regard to the breaking face advancing rate, and the areas of further research have been determined.

Keywords: underground mining, coal seams, longwall, roof caving increment, longwall face advanced, main roof, methane emission.

INTRODUCTION

The roof-caving increment is one of the main geomechanical parameters that determine safety and efficiency of mining shallow coal seams with long breaking faces [10]. There are primary (from the moment of longwall face department from the face entry to the first roof caving) and secondary (subsequent) main roof-caving increments. The primary roof-caving increment exceeds the secondary ones 3-4 times, so at the moment preceding the first main roof caving, roadway supports and safety structures are under the highest load. Accurate prediction of caving increments is necessary for both assessing possible loads on the roadway supports and sections of support [11, 12] and assessing possible coal sloughing from the heading faces, as well as for determining the frequency of the maximum methane release in the working area. Currently, several legal instruments are used in Russia for calculating main roof-caving increments [1, 3] with significant differences in their methods of calculation. On top of several calculation methods available, discrepancy between the actual roof-caving increments has been observed more and more frequently.

This work is aimed at increasing the efficiency of predicting main roof-caving increments when mining shallow coal seams with long breaking faces, based on analysis and improving existing methods of calculation.

METHODS

Roof-caving increments depend on the following main geological factors: thickness, structure, texture and strength of the main roof rocks, angle of occurrence, strength of the coal seam, and depth of the mining [2]. In addition, a number of researchers have noted the significant influence of such technological factors as the length of longwall face and breaking face advance rate on the main roof-caving increments [5, 7], and the need of adjusting existing methodological approaches [4, 6].

In various coal basins of Russia, various methods are used for calculating roof-caving increments. For example, in the Pechora coal basin, the method [3] developed in 1991 and republished in 2001 is used. In accordance with document [3], the primary l_{pr} and secondary l_{sec} main roof-caving increments are calculated by the following formula:

$$l_{\mathrm{pr}} = (3 \div 4) \cdot \mathrm{C} \cdot \sqrt{\sigma_{\mathrm{str}} \cdot T},\ \mathrm{m} \tag{1}$$

$$l_{\mathrm{sec}} = \mathrm{C} \cdot \sqrt{\sigma_{\mathrm{str}} \cdot T},\ \mathrm{m} \tag{2}$$

where C is the coefficient, which for easily caved roofs is equal to 0.4; for moderately caved roofs - 0.7, and for hard-caved and very hard-caved - 0.9; T is the active roof thickness taken equal to 5 coal seam thicknesses, and for very hard-caved roofs - to 10 coal seam thicknesses; and σ_{str} is the weighted average strength of rocks for stretching, kg/cm^2.

In the Kuznetsk coal basin, another method [1] is used that was developed in 1973, which additionally takes into account the advance rate and the length of the longwall face.

Primary r^o_{pr} and subsequent r^o_{sec} main roof-caving increments are determined by the following formulas [1]:

$$r^o{}_{init} = 36 \cdot (1+\sin\alpha)\frac{F^o{}_r\sqrt{V}}{\sqrt{D}} + 10.5 \cdot \sqrt{V}(1+\sin\alpha)e^{-0{,}7\frac{h^o{}_r}{F^o{}_r}} \tag{3}$$

$$r^o{}_{cons} = 10.5 * \sqrt{V}(1+\sin\alpha)e^{-0.7\frac{h^o{}_r}{F^o{}_r}} \tag{4}$$

where α is the angle of seam inclination, degrees; H is the depth of mining, m; D - the length of the longwall face, m; r is half width of the face space, m; f is the coal seam strength coefficient; F_{mr} is the main roof rocks strength coefficient; V is the average breaking face advance rate, m/day; and h_{str} is the area of the active rock stratification zone, m.

During the research, actual main roof-caving increments and the roof-caving increments calculated according to the applied methodology [3] were comparatively analyzed in the conditions of the mines of the Vorkuta Deposit in the Pechora basin. For the conditions of the mines of the Sokolovskoe deposits in the Kuznetsk coal basin, actual main roof-caving increments were assessed by changes in the periods of the maximum methane release in the working area, and the calculation results obtained by method [1] were comparatively analyzed.

RESULTS

Analysis of mining data about the actual main roof-caving increments for mines Vorkutinskaya, Zapolyarnaya, Komsomolskaya, Severnaya for the period between 2005 and 2015 allowed to generalize the data about caving increments steps, and to perform comparative assessments of the estimated and the actual main roof-caving increments (Table-1). It had been found that in almost 50% of the examined cases the actual initial roof-caving increment slightly exceeded the calculated range. Also cases of significant excess (by more than 20%) and significant lagging (over 30%) of the actual roof-caving increment, compared to the calculated one, were found.

The methods of determining the main roof-caving increment [3] for determining completeness and correctness of accounting for the influence of the major geological and mining factors in determining main roof-caving increments in the conditions of considerable variability in the lithologic rock composition and physical-mechanical properties had been analyzed.

It should be noted that method [3] explicitly states that they are based on the results of studies in rock pressure control in breaking faces in the mines of the Pechora basin, and normative, methodical and reference documents developed in the years 1979-1986 based on empirical data of that period are used. Thus, the considered method [3] can adequately reflect the real conditions and regularities of deformation processes and main roof caving in modern high-performance long breaking faces, and requires verification and correction.

Table-1. Data about main roof-caving increments in the mines of JSC Vorkutaugol.

Mine	Longwall face	Longwall face length, m	Seam	Initial main roof-caving increment, m			
				Calculated [3]		Actual	
				L_{in}	L_{sec}	L_{in}	L_{sec}
Zapolyarnaya	624-yu	222	Triple	50-67	16-17	n/a	20
Zapolyarnaya	314-s	201	Triple	56-75	13-19	75	20
Zapolyarnaya	113-yu	250	Fourth	25-33	8	40	8
Zapolyarnaya	724-yu	190	Triple	51-68	16-18	70	20
Zapolyarnaya	834-yu	255	Triple	45-60	13-14	57	55
Zapolyarnaya	414-s	195	Triple	51-68	20	70	20
Zapolyarnaya	514-s	222	Triple	48-64	16	60	15
Zapolyarnaya	514-s	297	Fourth	51-68	17	100	15-20
Zapolyarnaya	614-s	285	Fourth	57-76	19	100	20
Komsomolskaya	312-yu	240	Triple	-	-	80	-
Komsomolskaya	412-yu	300	Triple	-	-	95	-
Komsomolskaya	712-yu	250	Fourth	-	-	65	-
Vorkutinskaya	512-s	n/a	Triple	-	-	116	-
Vorkutinskaya	512-yu	217	Fourth	-	-	51-60	-
Vorkutinskaya	612-yu	200	Fourth	-	-	80	-
Severnaya	412-z	220	Mosshny	-	-	110	-

With the use of calculation methods of VostNII [1], diagrams of dependence of the initial main roof-caving increment on the advance rate of breaking faces had been built (Figure-1). The range of advance rates from 1 to 10 m/day was considered as the actual possible rate when using modern long breaking faces in the complicated mining-geological conditions of the Vorkuta Deposit in the Pechora coal basin. In the considered conditions with regard to the typical advance rates of breaking faces of 2.5 to 6.5 m/day, and the maximum up to 5-10 m/day,

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increasing the breaking face advance rate in seams Fourth and Fifth from 1 to 5 m/day might result in increasing the main roof-caving increments 1.1 to 2 times. Increasing the breaking face advance rate in Triple from 1 to 10 m/day might result in increasing the main roof-caving increments 1.3 to 3 times.

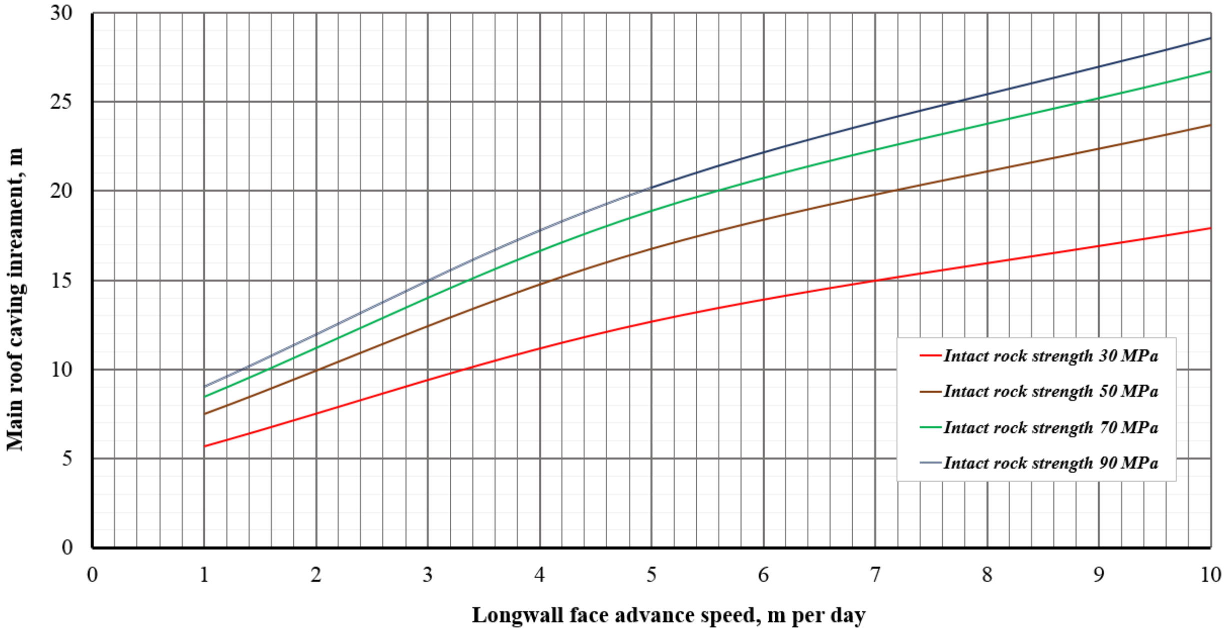

Figure-1. Dependence of the main roof-caving increment on the breaking face advance rate.

The studies performed in mine Kotinskaya (the Kuznetsk coal basin) showed the correspondence of the values of main roof-caving increments calculated according to the method that took into account the breaking face advance rate [1] to the actual values determined in the conditions of the mine. The correspondence between the calculated and the actual values of secondary main roof-caving increments was detected based on assessing the frequency of the maximum methane release in the working areas: as the breaking face advance rate increased, the period of maximum methane release decreased.

4. DISCUSSIONS

The performed analysis of the methods used for calculating main roof-caving increments [3] used in the mines of JSC Vorkutaugol showed that the main significant disadvantages of the computational method were the following ones:

- The absence of accounting for the influence of mine engineering factors (longwall face length, breaking face advance rate), which had significant effect on the main roof-caving increments. According to the preliminary estimates, for the range of longwall face advance rates of up to 5 m/day and the length of the longwall face 200-300 m, the change of the roof-caving increments might be up to 20%, compared to the calculated values obtained earlier based on empirical formulas.
- The absence of accounting for deformation-and-strength characteristics of the real rock mass, and their changes in the areas of unloading and original rock pressure. Since the strength properties of the tested samples had not reflected the strength of a real crevassed mass (especially the tensile strength limit), further research was required to introduce the structural weakening coefficient for transition from properties of the samples to properties of a real crevassed mass, which was particularly relevant for assessing the impact of undermining.

Accounting for the influence of each individual factor of the main geological and mining factors that determine roof-caving increments is complicated by their simultaneous action, with the result being that it is impossible to find the impact of each individual factor in the conditions of the mine. For example, the significant increase in the breaking face advance rates in the last 15 years should have resulted in increase in main roof-caving increments. However, during the same period, the length of longwall faces increased significantly, which resulted in reduced roof-caving increments. The impact of each of these factors in mining coal seams in the Pechora basin are understudied, and not used in the existing methods. Insignificant deviation of the actual roof-caving increments from the calculated ones obtained using method [1] in most cases is due to mutual multidirectional action of unconsidered mining factors, and significant range of variation of calculated main roof-caving increments.

The necessity of considering the breaking face advance rate due to its significant influence on the main roof-caving increments was noted by many researchers. With that, the growth of the effect of breaking face advance rate in the last decades was due to the multiple (up to 10 times and more) increase in the loads on the breaking faces due to the wide use of modern and reliable high-performance breaking complexes [8, 9, 13].

5. CONCLUSIONS

The analysis of the mining data about main roof-caving increments showed the significant difference between the calculated and the actual roof-caving increments, and confirmed poor efficiency of the methodological approaches outlined in calculation method [3], therefore its use might only be recommended for approximate assessment of the possible main roof-caving increment range.

The breaking face advance rate was one of the main geological and engineering factors that had significant influence on both initial and subsequent main roof-caving increments. The common pattern was the increase of the main roof-caving increment with the increase of breaking face advance rate. With that, the most significant changes of the main roof-caving increment were observed in the advance rate range of 1-5 m/day. The analysis of the existing methodological approaches [1] that considered the breaking face advance rate showed that increasing longwall face advance rate from 1 to 25 m/day might result in an increased subsequent roof-caving increments by 5 times. With that, the major factors that determined the possible influence of breaking face advance rate on the main roof-caving increment were the load on the breaking face, the length of the longwall face, and the frequency of breaking face operation.

Further research will be focused on refining the existing methods of calculating the main roof-caving increments with regard to the breaking face advance rate [1], and its use in a wide range of geological conditions of various deposits and basins in Russia.

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