ENTRY STABILITY IN STEEPLY INCLINED THICK COAL SEAM AT UNDERGROUND HYDRAULIC MINING

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ABSTRACT

Main objective of the executed researches was justification of the location of entry providing its maintenance in a bearing pressure zone. Researches were carried out for conditions of the Prokopyevsk and Kiselevsky field of the Kuznetsk coal basin (Russia). Researches were conducted by a finite element method. When performing researches the provision entry relative of a regional part of the massif and property of coal changed. As a result of researches influence of strength of coal and the location of entry on the stress and strain state of the massif is established and the conclusion is drawn on need of increase in height of a slice up to 10 m. Recommendations of increase in height of each subsequent slice at mining of soft coals are also made. The novelty of work consists in establishment of dependences of the stress and strain state of the massif on height of the mining slice.

Key words: underground mining, inclined thick coal seams, hydraulic mining, entries stability, strain-stress state, numerical simulation, finite elements method

1. INTRODUCTION

Hydraulic mining of coal is one of the most effective and safe ways of underground mining of steeply inclined coal seams. In Russia hydraulic mining of coal is successfully applied in the Kuznetsk coal basin at mining of steeply inclined coal seams of the Prokopyevsk and Kiselevsky field. The Prokopyevsk and Kiselevsky field is one of the largest fields of Kuzbass on coal reserves, however belongs to fields of very complex geological structure. In a stratigrafichesky section powerful seams of suite alternate with thin and an average thickness, and the distance between separate seams fluctuates in very wide limits. The coal field very gassy, and coals of the majority of seam are inclined to self-ignition. In such conditions questions of management of gas emission have considerable relevance [1-15]. In the area steeply inclined of seams prevails: the share of steeply inclined seams makes 90% of all stocks, including 57% - on seams with a inclination more than 60°. At steeply inclined of seams there is a slide down of the desintegrated coal and the broken-down rock, slide down of the endogenous fires from the above-located level. In such difficult conditions it is impossible to apply mechanization and longwall [16-23] and only hydraulic mining of coal provides effective and safe coal mining. As a perspective method of management of coal mining in such difficult geological and mining conditions it should be noted a method of the system analysis and management [24-29].

Coal failure at hydraulic mining is carried out by a hydro monitor with a pressure of water of 16 MPa and an expense of 400 m3/hour. Entry small on the cross-sectional area (4.8-5.2 m^2) have the trapezoid form of cross section and are carried out by a roadheading machine, a drilling-and-blasting way or a hydro monitor. Average depth of mining in the area is 200-400 m. With increase in depth of coal mining cases of destruction of a roadway support of entries in a zone of influence of bearing pressure from the goaf (the mined horizontal slices) therefore an important practical goal is justification of the location of seams (height of the mined slices) in various geological conditions for ensuring stability of entries even more often began to be observed. It should be noted that questions of geomechanical justification of parameters of technological schemes are relevant for the majority of mines [30-43].

2. METHODS

For studying of change of the stress and strain state of the massif of rocks around entries numerical researches were conducted by a finite element method. Geomechanical models of the massif of rocks and settlement schemes were developed. Key parameters of the settlement scheme (figure 1) are:

- thickness of a seam - m, m;

- seam inclination - α , degree;

- depth of mining - H, m;

- the size of the goaf - L, m;

- width of the pillar - Z, m;

- height of the slice - h, m;

- strain-strength properties of coal.

When carrying out a research the option of technology of development applied at mining of seam with a height 6-8 m which provides carrying out one entry within a horizontal slice was considered.

At the first stage of researches the key changeable parameter was the height of slice, Other parameters of the settlement scheme (figure 1), were accepted by constants: $m = 7$ m; $\alpha = 60^0$; $H = 300$ m; $L = 50$ m; $Z = 10$ m.
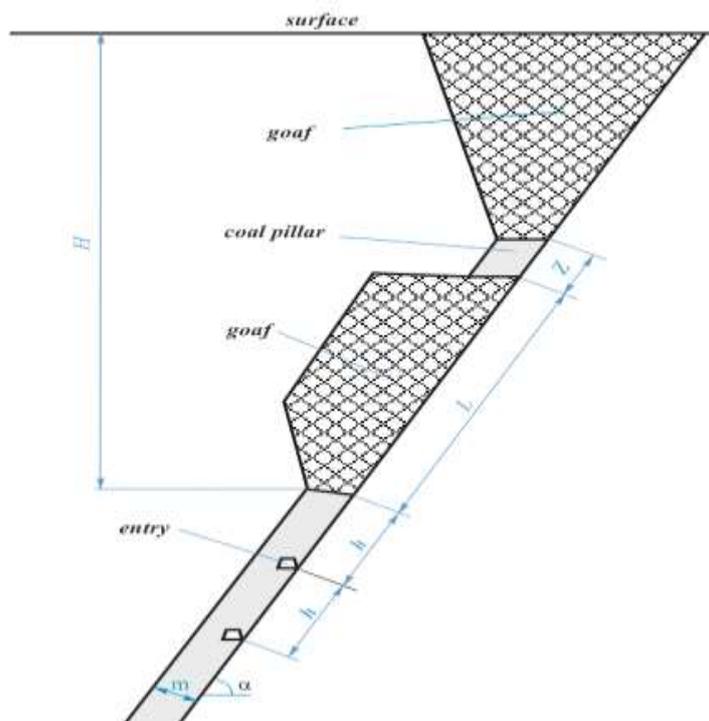
Figure 1. The settlement scheme for assessment of the impact of height of a slice on the stress and strain state of the massif of rocks in the neighborhood of the entry

The following stages of researches provided increase in height of the slice by 5 m. Thus all 3 options of height of the slice were modelled: 7 m, 12 m, 17 m. Modeling was carried out for coals with various strength: very strength, average strength and low strength.

3. RESULTS AND DISCUSSION

In figure 2 as an example of the received results stress distribution curve are shown with a height of slice of 17 m. Apparently from figure 2 in a zone of influence of bearing pressure from the goaf (earlier extracted slices) considerable concentration of stress is observed. However, increase in stress by 3 times is observed on the small site at a regional part of the massif. The entry shown in figure 2 does not come under influence of bearing pressure.
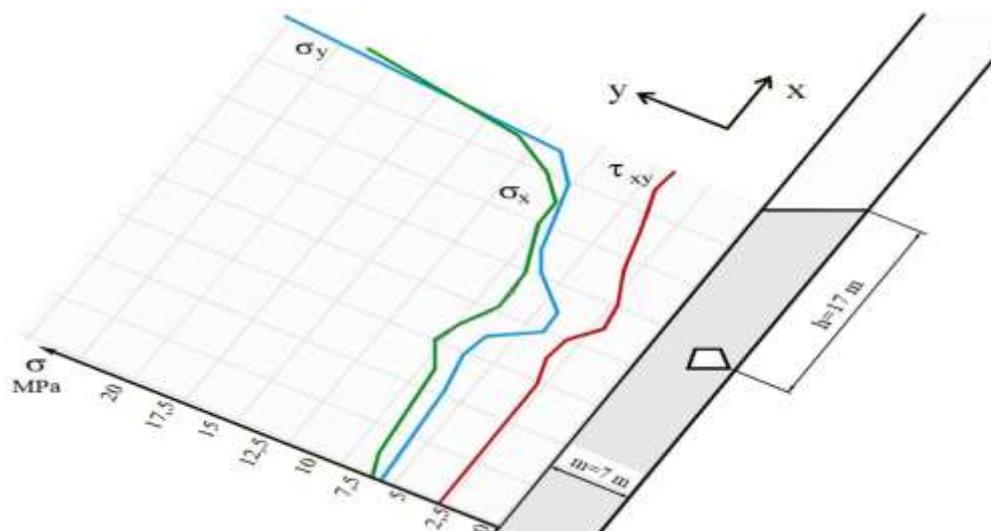

Figure 2. Stress distribution curve in the neighborhood of a entry at h = 17 m

In figure 3 isolines of plastic strain in a regional part of the massif with various height of a slice are shown. Figure 3,A shows that with the maximum height of a slice of h=17 m in a regional part of the massif on border with the goaf the zone of extreme limit deformations extending in the vertical direction down to depth about 6 m is formed. Also zones of a limit state are formed in the angles of the entry having the trapezoid form of cross section.

Reduction of height of a slice up to 12 m at mining of coals seam a low strength does not lead to high-quality changes of the provision of zones of an extreme limit state (figure 2, B), however, owing to strengthening of influence of bearing pressure from goaf, the extent of the specified zones in the field of influence of bearing pressure – between entry and the goaf - increases approximately by 20-30%. Besides, the level of plastic strain within the considered zones considerably increases.

Reduction of height of a slice up to 7 m results in arrangement of entry in the zone of an extreme limit state created at a regional part of the massif. Owing to what it is observed (figure 2, C) change of parameters of zones of ат extreme limit state around the entry: forms of zones in space and the level of plastic strain in their limits. Plastic strain cover completely all area from a development roof to a regional part of the massif (figure 2, B). Also the zone of an extreme limit state, essential by the sizes, at development from a layer roof is formed. Thus, there is an entry destruction.
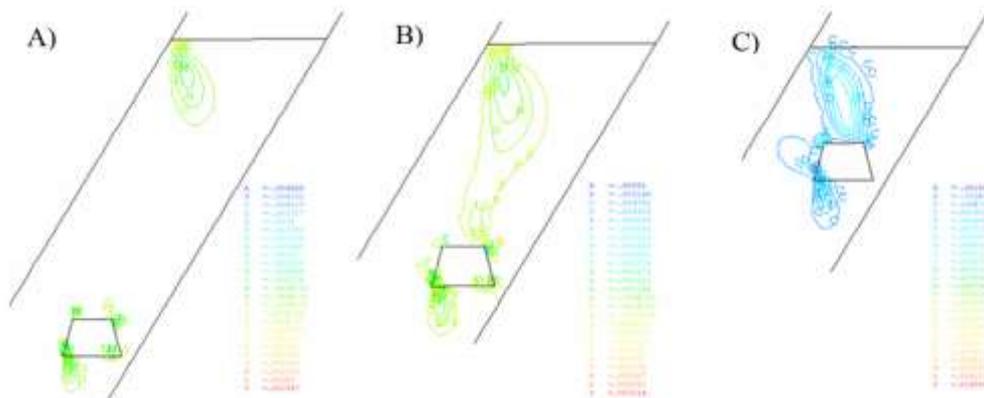

Figure 3. Plastic strain in the neighborhood of a entry in a zone of influence of mining with various height of the slice (weak coals): A) at h = 17 m; B) at h = 12 m; C) at h = 7 m

Results of numerical modeling of influence of strength characteristics of coals on the stress and strain state of the massif around entry are of considerable interest. In figure 4 isolines of plastic strain for various types of coals are presented: very strength (figure 4, C), average strength (figure 4, B), low strength (figure 4, A).
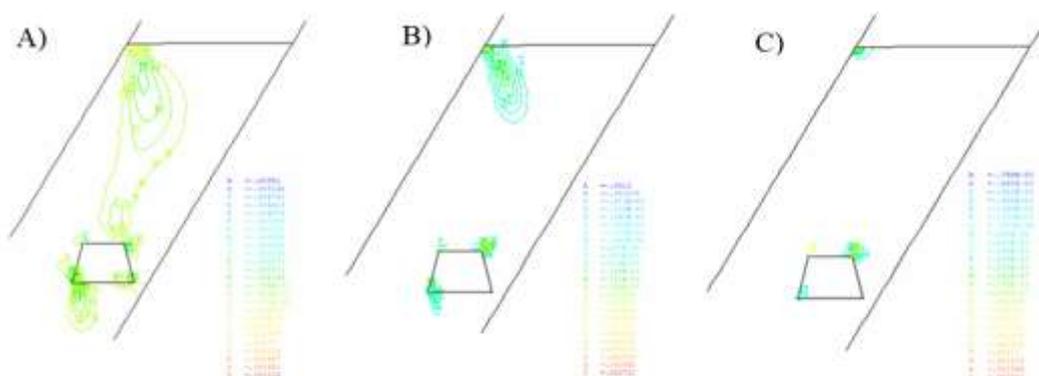

Figure 4. Plastic strain in the neighborhood of entry in a zone of influence of mining at various strength of coal: A) very strength; B) average strength; C) low strength

Figure 4 shows that strength characteristics of coal determine parameters of all zones of strain formed both at the goaf and at an entry. So, at mining of strength coals at the considered depths (300-400 m) when the level of loads in a zone of bearing pressure and strength characteristics (in this case strength on monoaxial compression) are approximately comparable, the sizes of zones of a extreme limit state are minimum. Decrease in strength of coal leads to the fact that the level of stress in a regional part of an entry exceeds extreme strength characteristics and a part of coal passes into a superlimiting state.

It should be noted that when performing researches properties of the main roof of seam which according to many researchers can define geomechanical conditions and safety of mining [44-50] were not considered.

4. CONCLUSIONS

As a result of the executed researches influence of height of the slice and strength of coal on the stress strain state of the entry located in a zone of bearing pressure is established.

By results of researches the following main conclusions are drawn:

- - Stability of entry in zones of bearing pressure, when mining of seams at depths more than 300 m and arrangement of an entry at distance less than 15 m from regional parts of the massif (height of a slice less than 15 m), is defined by coal strength. At increase in the specified distance up to 15 m and more - the significant influence of the goaf and a zone of bearing pressure upon a condition of an entry is not revealed.

- - The steady condition of entry during all term of their life time at depths of 300 m can be also more provided with a slice height (distance from entry to a regional part of the massif) not less than 10 m;

- - Distribution of a zone of extreme limit strain in the neighborhood of local entry and the level of deformations in the specified zone, with other things being equal, are defined by coal strength.

- - At mining of low strength coals increase in height of the fulfilled slice for decrease in influence of bearing pressure and ensuring stability of entry is recommended gradual (in process of increase in number of the fulfilled slices and the sizes of the goaf).

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