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# The Extent of Destruction Zones Within Protective Pillars in Jsc "Suek-Kuzbass" Underground Mines

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**Abstract.** To justify an effective way of extracting protective pillars, which have lost their primary function, we need to establish the extent of destruction zones within them. This problem has been tackled using the finite element method allowing for their relative position, the depth of cover, the structure, and the deformation and strength properties of the strata.

## 1 Introduction

Pillar size calculation is one of the classic problems of geomechanics, whose solution has been the subject of multiple publications [1]. In terms of definition and solution methods, these publications can be divided into two categories: (1) engineering solution methods based on re-distribution of rock stress, and (2) methods based on the mechanics of a deformed solid body. Being the most physically stringent, the methods based on the mechanics of a deformed solid body include the finite element method, a boundary element method and analytical methods [2-11]. This article is based on a finite element method [12] which takes into account deformation and strength properties of the complete coal compression diagram [13].

## 2 Materials and methods

The analysis of the strength of protective pillars is shown using an example of pillars for slopes in Rubana Mine, JSC "SUEK-Kuzbass". This mine is extracting three gently dipping seams:

1) Polysaevsky-II Seam, depth of cover 80 – 124 m, angle of dip 6 – 8$^0$, thickness from 4.40 to 5.4 m;

2) Nadbaikaimsky Seam, depth of cover 210 – 290 m, angle of dip 3 – 7$^0$, thickness from 2.20 to 2.70 m;

3) Baikaimsky Seam, depth of cover 245 – 285 m, angle of dip 5 – 12$^0$, thickness from 2.20 to 2.85 m.

The schematic of the relative position of these seams allowing for planned mining operations in all three seams is shown in Fig. 1.

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The solution of the problem takes into account the structure of the strata and properties of each layer specified for wells 21577, 21567, and 11724.

The computational region of the problem was defined taking into account the depth and the thickness of the existing layers. The properties of the rocks were set in the following way:

For topsoil with alluvium the deformation module is $E = 4 \cdot 10^9$ N/m$^2$; Poisson's ratio is $\nu = 0.3$; bulk density is $\gamma = 18000$ N/m$^3$.

For siltstone: $E = 1 \cdot 10^{10}$ N/m$^2$; $\nu = 0.25$; $\gamma = 25000$ N/m$^3$.

For sandstone: $E = 2 \cdot 10^{10}$ N/m$^2$; $\nu = 0.2$; $\gamma = 27000$ N/m$^3$.

For coal seams: $E = 1 \cdot 10^9$ N/m$^2$; $\nu = 0.25$; $\gamma = 13000$ N/m$^3$.

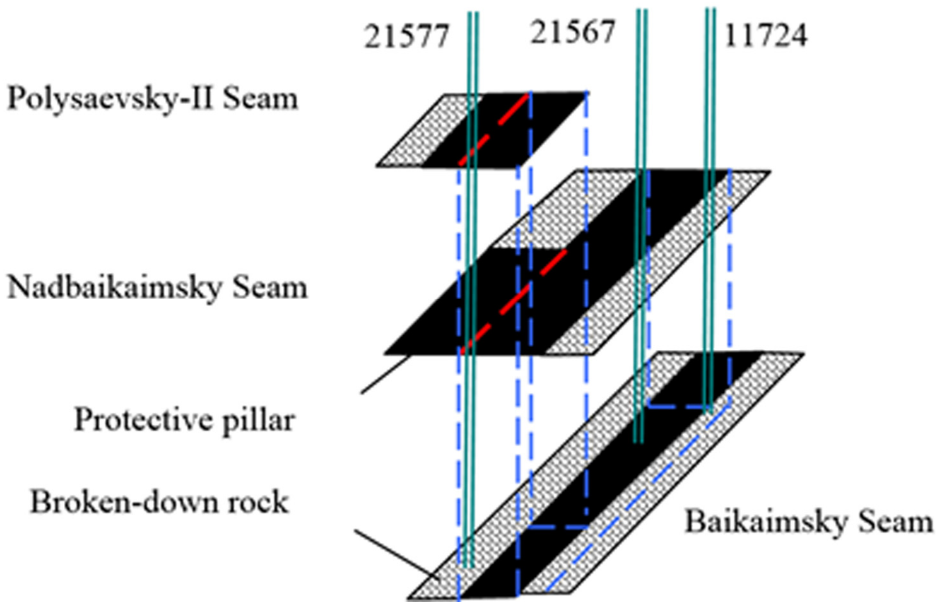


**Fig. 1.** Scheme of location of protective pillars for coal seams with the indication of wells – border of protective pillars

Fig. 2 shows vertical profiles and calculation schemes for the stressed protective pillars for slopes through wells 11724 (a), 21567 (b), and 21577 (c) respectively.

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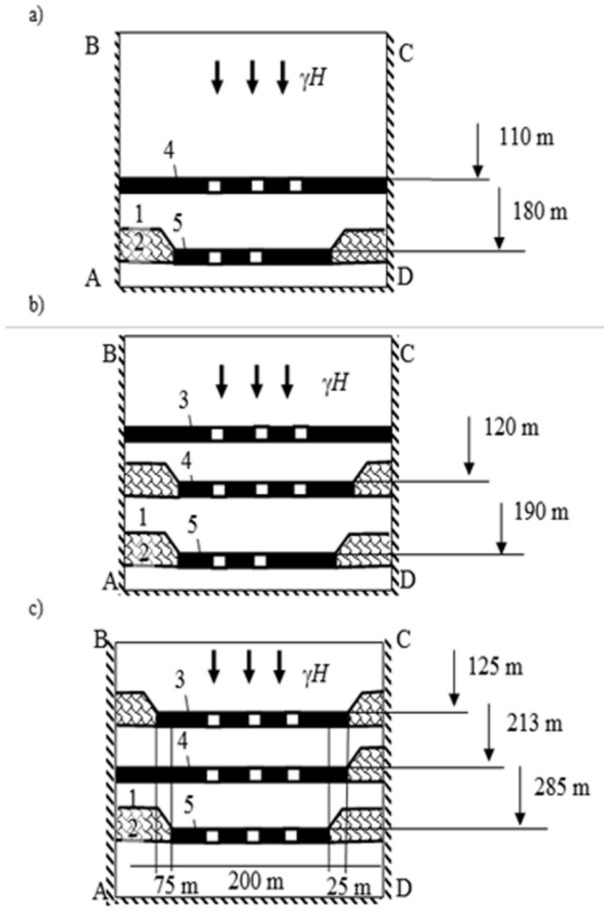


**Fig. 2.** Vertical profiles and schemes for calculating the strength of protective pillars through wells 11724 (a), 21567 (b), 21577 (c) respectively: 1 – host rock; 2 – goaf; 3 – Polysaevsky-II Seam; 4 – Nadbaikaimsky Seam; 5 – Baikaimsky Seam .

The problem at hand was solved using finite element method with ELCUT licensed software package. The number and size of grid elements were selected in such a way that boundary conditions are fulfilled with adequate accuracy: up to 0.001 m for movements and up to 1 N/m$^2$ for stresses.

The condition of the pillars was modelled based on a developed methodology for numerical calculation of the condition of pillars taking into account superlimiting deformation [14].

A criteria introduced in V.A. Gogolin's publication [13] was used for assessing pillar strength. The ultimate strength of a gently dipping seam which is in a planar deformation state is calculated using the following formula:

$$\sigma_s^p = \gamma H + \frac{\sigma_s}{1+\nu}, \tag{1}$$

where ν – lateral deformation ratio; $H$ – depth of cover (m); γ – bulk density of rocks (N/m$^3$); $\sigma_s$ – ultimate monoaxial compressive strength of rock (MPa).

So the section of the seam which meets this requirement: $\left|\sigma_{yy}\right| > \sigma_s^p$ , loses its strength, partly breaks down, thus goes into a superlimiting state.

The following values were used in the calculations: ν = 0.25; $\sigma_s$ = 10 MPa.

Fig. 3 shows distribution of vertical stresses within the section of well 11724 (upper section). Within this profile a protective pillar in Baikaimsky seam is being analysed (see Fig. 2a). The maximum compressive stresses at which the coal seam retains its strength were calculated using this formula (1): $\sigma_s^p = -14{,}5$ MPa. Sections of the seam where $\sigma_s^p < -14{,}5$ MPa and which lose their strength are shown in purple. The length of the destruction zone both sides of the pillar is 3.7 m.

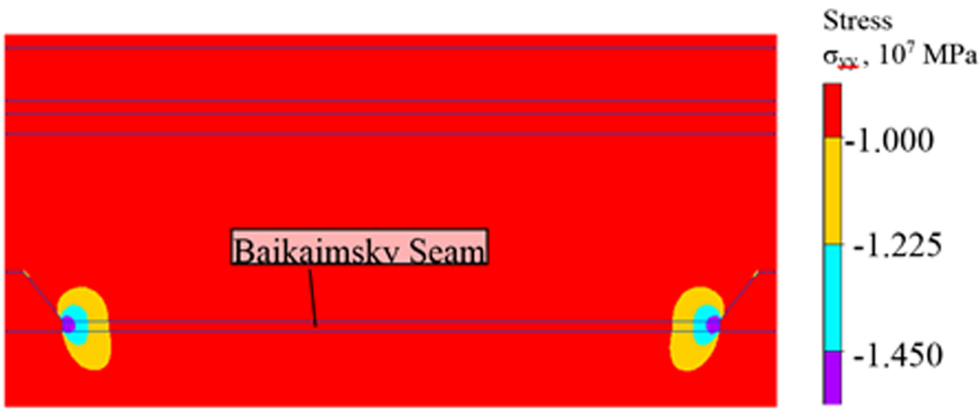


**Fig. 3.** – Distribution of vertical stresses $\sigma_{yy}$ in section of well 11724.

Fig. 4 shows distribution of vertical stresses within the section of well 21567 (middle section). Two protective pillars are located within this section.

For Baikaimsky Seam the ultimate strength is $\sigma_s^p = -15$ MPa. Destruction zones in this seam are shown in purple and amount to 2.2 m on the left-hand side and 2.7 m on the right-hand side. For Nadbaikaimsky Seam $\sigma_s^p = -14$ MPa. The destruction zone is shown in purple and blue and amounts to 0.8 m on the left-hand side and 0.6 m on the right-hand side.

Fig. 5 shows distribution of vertical stresses within the section of well 21577 (see Fig. 2b). Three protective pillars are located within this section.

For Baikaimsky Seam the ultimate strength is $\sigma_s^p = -17$ MPa. Destruction zones in this seam are shown in purple and amount to 8.2 m on the left-hand side and 8.8 m on the right-hand side. For Nadbaikaimsky Seam $\sigma_s^p = -15$ MPa. The destruction zone is shown in purple and blue and amounts to 2 m.

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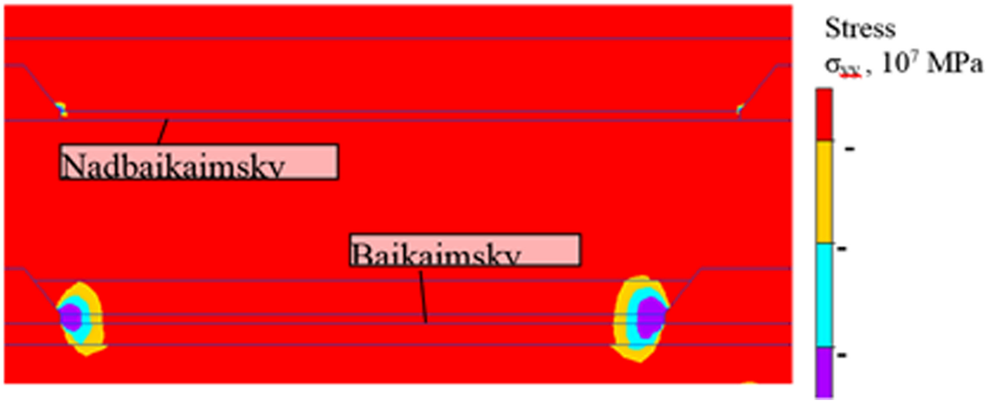


**Fig. 4.** –Distribution of vertical stresses $\sigma_{yy}$ in section of well 21567

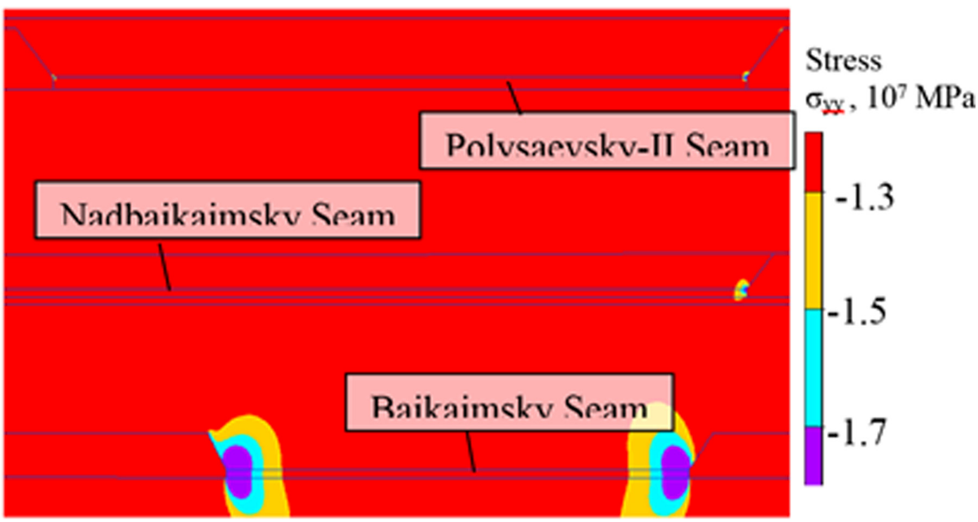


**Fig. 5.** – Distribution of vertical stresses $\sigma_{yy}$ in section of well 21577.

For Polysaevsky-II Seam the ultimate strength is $\sigma_S^p = -13$ MPa. The destruction zone in Polysaevsky-II Seam is shown in purple, blue and yellow. Its sizes are 1.1 m on the left-hand side and 2.6 m on the right-hand side.

## 4 Conclusions

The deduced sizes of destruction zones within the boundary parts of protective pillars for slopes should be considered during design of a technology for extracting them. In particular, the amount of coal within these zones will be accounted for as operational losses. For pillars in Nadbaikaimsky and Polysaevsky-II seams these losses will amount to 1-1.5% while in Baikaimsky seam the losses will reach 3.7%, 2.5% and 8.5% in the upper, middle and lower part of the pillar respectively.

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