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# Stress-strain state of rock mass around pillars and chambers considering the angle of occurrence of the ore body

**Abstract**: The task of the study is to determine the parameters of the unstable-deformed state of the rock mass around the targets and the chamber at various angles of occurrence of the ore body. A vertical section of a rock mass is considered. The deformation along the chamber can be neglected and the task is reduced to flat. The number of methodical finite elements is taken as the solution method. To solve the problem, the characteristic conditions of cleaning chambers and tar-gets are modeled. The geometric parameters of the design scheme succeeded with the maximum approximation to real conditions. The characteristic of a solid body and host rocks is given by the modulus of elasticity, Poisson's ratio, and volumetric weight.
**Keywords**: rock mass, cleaning chambers, host rocks, tensile stresses, multidimensional mathematical models.

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## Introduction

Underground mining of flat and inclined ore deposits with an open mining area causes the abandonment of both inter-chamber and protective (barrier) pillars. Known works show that the main methodological approach in calculating the parameters of the pillars is to determine the reaction of the resistance of a unit area of the ore massif to the acting loads falling on this area. In this case, the acting load is taken from the calculation of the entire column of rocks or within the limits of the arch of natural equilibrium. Both approaches have sufficient grounds for use in determining the dimensions of the pillars. However, they are acceptable when the rock top layer is represented by a homogeneous massif and it is possible to form an equilibrium dome. However, in cases of intermit-tent deposits and in the presence of layered rocks of different strengths, the known methods do not allow the calculation of the dimensions of technogenic spaces, including pillars, with sufficient accuracy. When calculating the parameters of the pillars, they exceed their optimal values, and this leads to the loss of a mineral or to premature collapse of both the pillars and the roof of the chambers and panels.

Thus, the development of technology for the extraction of flat and inclined ore deposits based on an array of powerful quantum-deformed states (QSS), and their influence on the elements of the system, is an important scientific and technical part (Veksler & Tutanov, 1988; Abikak et al., 2023).

## Research analysis

The task of the research is to determine the parameters of the stress-strain state (SSS) of the massif, which affects the stability of pillars and treatment chambers, considering creep.

To process studies to determine the stress-strain state of a rock mass, in particular, to determine the stable dimensions of supporting pillars and chambers during field development, using an unconventional method for constructing multidimensional mathematical models, we obtained the following mathematical model, which considers a complex of natural and man-made factors:

$$\sigma_1^{max} = f(\gamma H, b_2, b_1, h_2, E, h_1),$$

where E is the modulus of elasticity of host rocks, γH - is the load (natural factor), σ1max - is the maximum principal stress, b2 - is the height of the pillar, h1 - is the width of the barrier pillar, h2 - is the width of the inter-chamber pillars, b1 - is the width of the chamber (Ermekov & Makhov, 1990).

The maximum principal stress is chosen as a function. At the same time, the following dependences of the function on the arguments were obtained:

$$\sigma_1^{max} = 5.34291*\gamma H**0.634218- 5.16712,$$

$$\sigma_1^{max} =0.128656*e**(0.116583*b_1) +0.52904,$$

$$\sigma_1^{max} =1.16471 – 3.2359 / h_1,$$

$$\sigma_1^{max} =1.65676*e**(-0.0000081*E ),$$

$$\sigma_1^{max} =-0.00789461*b_2 **2+0.0577526*b_2+1.04593,$$

$$\sigma_1^{max} =58.3137*h_2 **(-1.47219) – 3.7791,$$

The correlation coefficient R = 0.965, and the analytical equation is as follows:

$$Y(\sigma_1^{max}) = Y(\gamma H)*Y(b_1)*Y(E)*Y(b_2)*Y(h_1) + Y(h_2)$$

When solving the problem, the parameters (technological, mining and geological factors) were changed in the following limits:

$b_1$ = 4÷16 (m) – chamber width at 3 m intervals;

$b_2$ = 3÷11 (m) – power to be withdrawn (pillar height) at 2 m intervals;

$h_1$ = 15÷27 (m) – width of the barrier pillar at 2 m intervals;

$h_2$ = 5÷9 (m) – width of inter-chamber pillars at 1 m intervals;

γH = 3.75÷18.75 (MPa) – pressure at 3.75 MPa intervals;

$E_{sur}$ = $3.2*10^4÷9.6*10^4$ (MPa) – modulus of rock elasticity with an interval of $1,6•10^4$

The following values are taken as the basic version of the calculation:

γH=7,5 MPa (300 m.), B2=7 m., $E_{sur}$=32000 MPa, h1=15 m.

In order to determine the influence of inclination angles of the ore body, the paired dependences were initially obtained. The allowable compressive and tensile stresses were chosen as a function (Amusin & Linkov, 1973). The following dependences of allowable stresses on the inclination angles were obtained, for tensile allowable stresses:

$$\sigma_{adm} = 0.34 \alpha – 0.65, \quad (1)$$

for compressive allowable stresses:

$$\sigma_{adm}=1.68\ \alpha-3.2, \qquad (2)$$

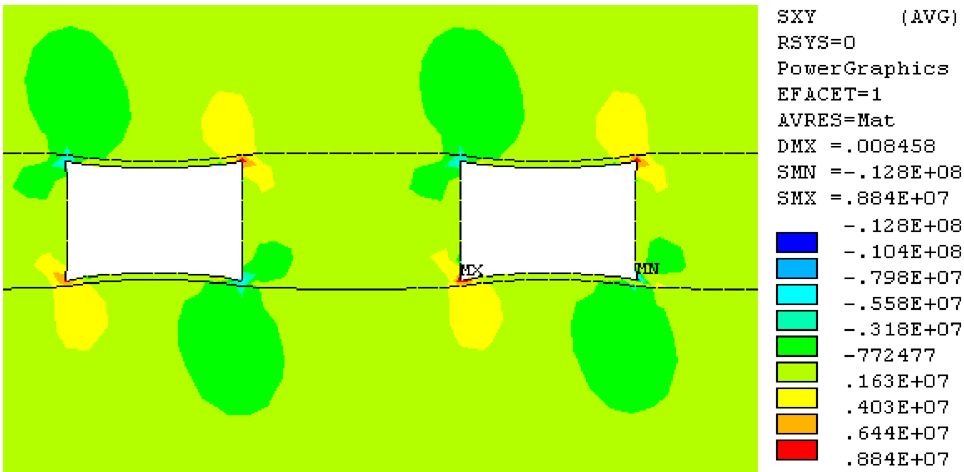
Further, to process research to determine the stress-strain state of a rock mass, in particular, to determine the stable dimensions of supporting pillars and chambers during the development of ore deposits, using a non-traditional method of building multidimensional mathematical models, we obtained a mathematical model that considers the complex natural and anthropogenic factors (Tutanov, 2011; Hu et al., 2015).

The maximum principal stress was chosen as the function. The dependences of the function on the arguments and equation were obtained (Beisembaev et al., 2013).

In order to obtain an equation considering inclination angles instead of allowable tensile stress expression (1) and by formula, obtained for the multidimensional model, we can find complex of factors influencing the stability of pillars and chambers (Shpakov et al., 2015).

Figures 1 and 2 show values of tangential and vertical stresses around chambers. Analysis of tangential and vertical stresses shows that around chambers and pillars, there are tensile stresses, i.e. stresses with positive signs, which increase with the increase of inclination angle. The zone of shear tensile stresses arises in the angular points of the chambers, and the vertical tensile stresses arise in the roof, the ground, and on the sides of the workings (chambers). This indicates that, when the limit stresses occur, rock failure will occur in these areas (Tutanov & Tutanova, 2020).

$\alpha = 0^0$




$\alpha = 10^0$

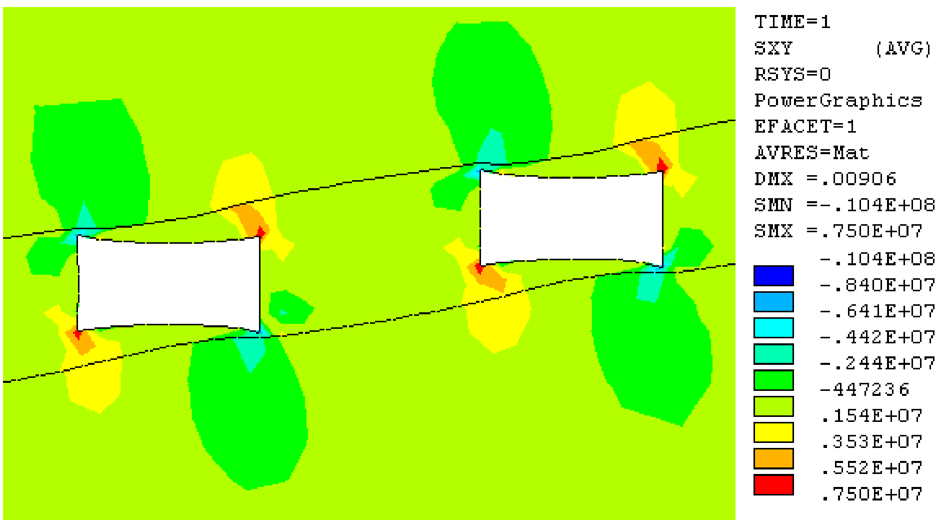
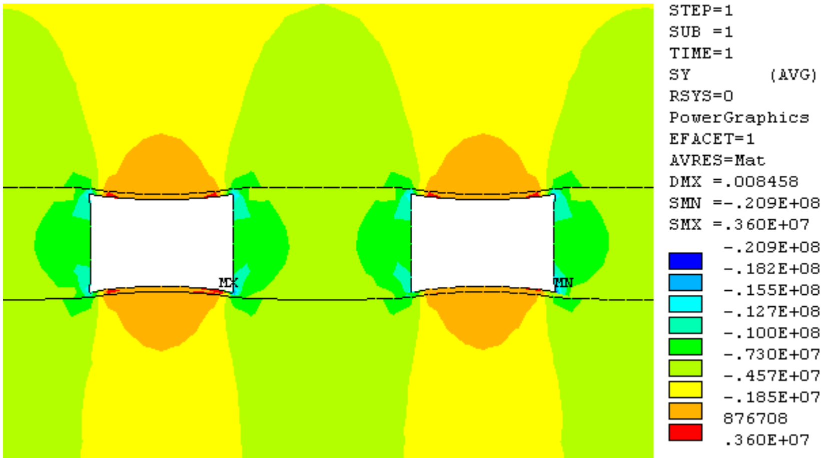



**Figure 1** - Tangential stresses in the roof, soil and at their junction with the pillars

$\alpha = 0^0$




$\alpha = 10^0$

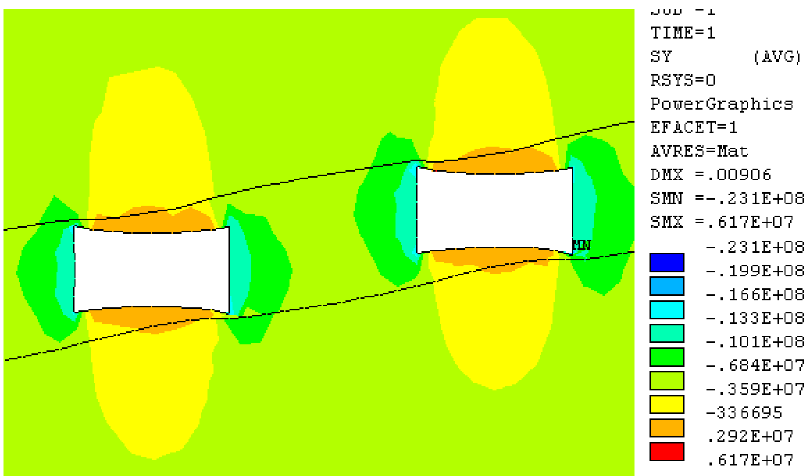
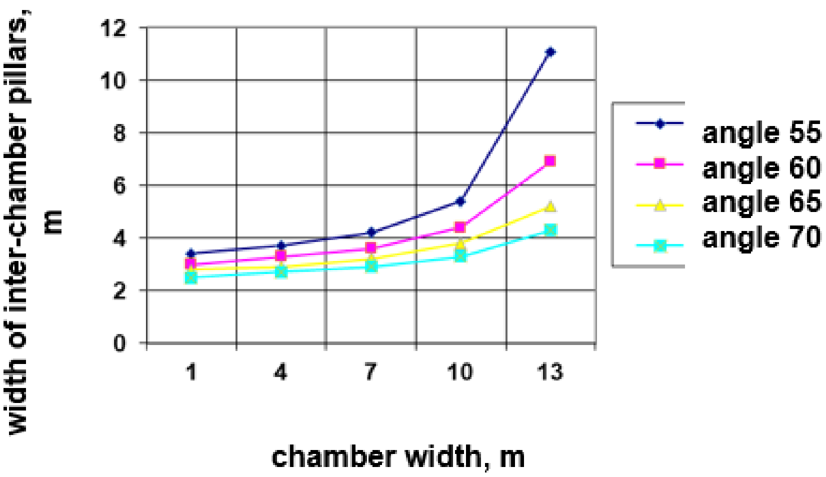



**Figure 2** - Vertical stresses in the roof, soil and at their junction with the pillars




γH=7,5 MPa (300 м.), $\sigma_{adm}$=0.34 α – 0.65, B2=7 m., $E_{sur}$=32000 MPa, h1=15 m.

**Figure 3** - Dependencies of pillar widths on b1

Thus, the mutual influence of the width of chambers and supporting pillars at different angles of inclination changes according to the obtained curves (Figure 3). Approbation of the methodology for changing conditions of Zhezkazgan was obtained by (Tutanov et al., 2020). At the same time, the dependence of pillar width on various factors, reflecting the main structural elements of the technology of development, was studied.

## Conclusion

To sum up, the research methodology allows to establishment of technologically necessary ratios of elements of development systems (parameters of pillars, chambers, panels, etc.) depending on specific conditions. In this case, the optimization of parameters will affect the level of normative losses and stability for the time of excavation of reserves.

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