DEVELOPMENT OF MEASURES TO ENSURE THE STABILITY OF A ROCK MASSIF WITH THE USE OF MODERN SURVEYING INSTRUMENTS

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Annotation: in the development of a mineral deposit by an underground method with the collapse of the overlying strata of the rock mass, failures and collapse zones form on the earth's surface. Dips and collapse zones on the earth's surface are used as a disturbing factor that cause a redistribution of stresses in the rock mass. The resulting cavities filled with collapsed rocks can be approximated on the earth's surface by a circle or an ellipse. A technique and schemes are proposed for calculating stresses when a collapse zone reaches the earth's surface in the form of a circle, using the results of observations of the displacement of benchmarks on the earth's surface along profile lines.

Keywords: collapse zone, rock mass, stress state, geodetic instruments, profile lines, benchmark, dip.

Currently, the development of measures for the protection of buildings, structures and natural objects in the development of powerful iron ore deposits by an underground method remains an urgent problem. In the work of N.P. Vloha , A.D. Sashurina and A.V. Zubkov [1] substantiated the need to determine the integral stress field at large bases in order to ensure the safety of mining operations in areas of mine fields from hundreds of meters or more, as well as to calculate the parameters of safety pillars and develop measures to protect buildings and structures on the earth's surface from their mining jobs.

Modern methods [2–4] make it possible to assess the safe state of buildings, structures, and natural objects during the displacement of rocks and the earth's surface, in which the gradients of the natural stress field acting in the rock mass are used as boundary conditions for calculation.

As a disturbing factor in the natural stress field, a dip formed in the rock mass and a collapse zone above the goaf, the shape of which on the earth's surface can be approximated by a circle or an ellipse [5–8], are used.

To determine the stresses, it is necessary to lay an observation station on the earth's surface according to a specially developed "Project", observing the requirements of the "Instructions for Observing the Movement of Rocks and the Earth's Surface during the Development of Ore Deposits" [9] and GOST 24846-

2012. Soils. Methods for measuring deformations of the foundations of buildings and structures [10].

Reference ground benchmarks are laid outside the zone of possible deformations, at least two points, both on the side of the hanging and lying sides of the ore body. The distance between the reference benchmarks must be at least 70 meters. As reference benchmarks, it is recommended to use the axial points of shafts and mine buildings, triangulation and polygonometry points, if they are located outside the zone of possible displacements.

Working benchmarks are laid at distances of not more than 5 radii (R) of the calculated (design) collapse zone. The layout of profile lines and benchmarks can be different:

- profile lines across the strike

ore body ;

- profile lines at an angle of 45˚ to the strike of the ore body (Fig. 2); • arrangement of working benchmarks in a checkerboard pattern;
- combined schemes.

Currently, in the production of mine surveying, modern high-precision electronic devices (electronic total stations, scanning systems, GPS and GLONAS navigation systems) are used, which allow changing the methods of geodetic and mine surveying to address industrial safety issues in the development of mineral deposits. The use of high-precision geodetic electronic devices makes it possible to increase the accuracy of determining the coordinates of working benchmarks, which are separated from the reference benchmarks at distances from one hundred meters to kilometers, with an accuracy of 2 mm. Significantly reduce the time for the production of geodetic measurements.

Consider a method for determining the stress state of a rock mass for the collapse zone represented on the plan as a circle. Reference ground benchmarks are laid at a distance of more than 5 radii from the center of the calculated collapse zone. Under this condition, the redistribution of stresses around the formed collapse zone in the rock mass and on the earth's surface will not affect the displacement of the reference benchmarks. After laying the observation station before the exit of the collapse zone, the planned coordinates of the ground reference and working benchmarks (xi; yi) are determined from two series of observations.

After the collapse zone reaches the earth's surface, a tacheometric survey is performed, based on the results of which a plan is made on a scale of 1:500 with the contours of the collapse zone and the crack zone drawn.

Using well-known analytical methods, the area of the collapse zone is determined, the planned coordinates (x 0; y 0) of the center of gravity are found [11]. The radius (R) of the collapse zone is calculated by the formula:

$R = \sqrt{S / \pi}$, where R and S are the radius and area of the collapse zone, respectively.

We introduce a new coordinate system (x`o`y` ) , the beginning of which is combined with the center of gravity of the formed zone of collapse on the earth's surface. In the new coordinate system ( x`o`y `) the y ` axis is combined with the x-axis, and the x` -axis with the y-axis for further convenience of transferring the coordinates of the reference and working reference points to the new coordinate system.

When the collapse zone reaches the earth's surface, the working benchmarks move, which leads to a change in their planned coordinates. With the help of high-precision electronic devices, we determine the new planned coordinates and increments of the coordinates of the working benchmarks located in the displacement zone on the earth's surface in the new coordinate system. The value of the total horizontal displacement of the i- th benchmark in the plan after the collapse zone reaches the earth's surface is determined by the formula:

Δy`2 i where Ɛ $i$ is the absolute horizontal displacement of the i- th benchmark; Δ $x$ ` i , Δ y ` $i$ are the increments of coordinates of the i- th reference along the x` and y` axes in the new coordinate system after the exit of the collapse zone. Scheme of displacement of the working i - th benchmark after the exit of the collapse zone to the earth's surface. The direction of the total horizontal displacement (shift) of the i- th reference is characterized by the angle φi relative to the y-axis ` φ i = arctg Δ $x$ ` i . Δ y ` i

From the scheme presented, we determine the radius - the vector of the i- th frame in the new system $\upsilon\theta i$ = Ɛ i $sin\delta i$; δi =90˚-βi– φi , (7) where υri , $\upsilon\theta i$ are respectively the radial and tangential displacements of the i- th reference; Ɛ i is the total horizontal displacement of the i- th benchmark; δi is the angle between the vector of the total horizontal displacement of the i- th frame and the radius - the vector of the i- th frame.

Radial and tangential displacements of benchmarks in the zone of influence of the dip and the zone of collapse on the earth's surface are determined using the following formulas [12, 13]: coordinates before the exit of the zone of collapse on the earth's surface according to the formula:

$ri = \sqrt{y`2\, i + x`2\, i}$, where x ` $i$ , $y$ ` i are the planned coordinates of the i- th frame in the new coordinate system (x`o`y `) before the collapse zone exits to the earth's surface. The direction of the radius-vector of the i- th frame before

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the exit of the collapse zone in the new coordinate system is determined by the formula: βi= arctg $y'i\ x'i$ Radial and tangential displacements of the i-th benchmark are calculated by the formulas:

{ υri = $\mathcal{E}i\ cos\delta i$ { $\nu\theta$ = −where νr , $\nu\theta$ are radial and tangential displacements; σ1, σ2 are principal normal stresses; R is the dip radius; r is the radius vector of the frame; G= E – shear modulus; E is the modulus of deformation-2(1+ μ) tion ; μ is Poisson's ratio; χ = 3− μ 1+ μ officer Kolosova G.V .; θ is the angular coordinate of the frame counted from σ1 to the radius vector of the frame counterclockwise.

To determine the stresses σ1, σ 2 , the angle θ and the shear modulus G, four equations must be drawn up. To compile four equations , it is enough to know the magnitude and direction of the total horizontal displacement vectors of two working reference points. The solution of the resulting system of equations will allow to determine the main normal stresses σ1, σ2, , the shear modulus G and the angle θ1 between σ1 and the radius vector of the reference 1. The direction of action of σ1 relative to the x' axis is determined using the following formula: α=β1-θ, where α is the angle between the x-axis` and the direction of action σ1; β1 is the angle between the x-axis` and the radius - the reference vector 1.

To determine the integral stress field after the collapse zone reaches the earth's surface, all possible options are sorted out and the accuracy of determining the components of the natural stress field acting in the horizontal plane and the rock shear modulus for a territory equal to the area of a circle with a radius equal to five collapse zone radii is performed. Observations of the development of the collapse zone in the process of mining and long-term geodetic observations of the displacement of benchmarks make it possible to monitor the stressed state of the rock mass, taking into account the size of the area undermined by mining.

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