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PARAMETERS OF SINGLE ANCHOR EFFECT AREA IN HOMOGENEOUS BORDER ROCK MASS

Analysis of basic methods to increase stability of mine workings is carried out. Objective of the paper is to study and determine area of single anchor effect on border mass at different anchor length, mining depth and physical and mechanical characteristics of enclosing rocks. Results of mathematical simulation of mine working located in homogeneous rock mass and fixed by single anchor are given. The research was based on the data of surveying regularities in changes of border mass strain-stress behaviour and amounted to the determining of expected displacement of natural mine working contour. Dependences of changes in single anchor effecting border rock mass upon anchor length, the working depth, and physical and mathematical characteristics of rock are obtained. Rational dimensions of single anchor effect area on border mass upon the anchor length, the mine working depth and physical and mathematical characteristics of rock are determined. Efficient anchor length for the mining and geological conditions is defined. Further research will be focused on studying effect of single anchor in heterogeneous border rock mass.

Keywords: anchor, mathematical simulation, border rock mass, mine working.

Introduction. Year by year the problem of stable underground mine workings becomes more and more important. This component of mining enterprise effects considerably cost-performance ratio of mines due to rapid deepening of mining operations, deteriorating of mining and geological conditions as well as increasing in general length of mine workings.

In practice measures to improve mine working stability are rejected because they require additional costs but the resulting losses turn to be unjustifiably high. It depends on collateral losses due to deterioration of mine working conditions foremost as a result of poor transportation and ventilation.

Reliable support is possible only in case when its structural parameters are selected taking into account size and features of rock pressure. If some factors are underestimated then support is inefficient even under relatively favourable mining and geological conditions.

While analyzing the results of scientific observations, most researchers have made conclusions that no technologically possible and economically efficient frame support of mine workings within deep rocks can resist rock pressure to the full. Consequently, it is not efficient to deal with developing breaking zones by means of increasing load-bearing capacity of support [1,2].

Main tendency of ensuring mine working stability, reducing materials consumption, working capacity, and cost of support is to use load-bearing capacity of rock mass (together with support) that can be achieved by timely filling the gaps of the behind support area by solidifying materials of the required strength as well as mass hardening by cementation and anchoring.

Mine working anchoring is the advanced and efficient method to support its stability. However, substantiation of rock anchor parameters is still the problem to be solved [3,4].

Anchoring is used both independently and in combination with other support types: shotcreting (with possible reinforcement with metal elements or meshwork), solid concrete (reinforced concrete), metal and concrete, tubbing, and blocking to ensure stability of mine workings. Anchors can be used independently or in combination with metal mesh as temporary bordering support as well [5, 6].

Anchoring is the system of roof bolts fixed in holes arranged in the specified order in the rocks enclosing mine working. Along with the supporting elements they are meant to consolidate rock mass and increase stability of its exposure.

Principle feature of such a support is as follows: roof bolts reinforce rock mass making it possible to use its own load-bearing capacity; in most cases that helps to prevent using standard supporting types or its required load-bearing capacity decreases considerably. Being used correctly, anchoring allows to secure mine workings safety and their proper maintaining under various mining and geological conditions; that concerns both stratified and unstratified fissured rocks beyond stoping area and in it; mine workings with different sectional shapes (as constant or temporary support), independently or in combination with other support types at minimum material and labour consumptions.

Other important advantage of anchoring is the reduction of cases of mine workings being out of order, increased safety level of their maintaining operations, rundown of timbermen.

Rated depth of mine workings, rated rock mass resistance to pressure, and category of rock stability are used as the basic estimated data to select anchoring type and parameters.

Main parameters of anchoring include its load-bearing capacity, roof bolt length, anchoring density, i.e. distance between anchor rows and between anchors in a row.

Analyzing single anchor-anchor system interaction with rock mass in particular applying analytical methods is quite a complicated problem that can be solved only by means of numerical simulation to have correct results.

Objective of the paper is to study and determine area of single anchor effect on border mass at different anchor length, mining depth and physical and mechanical characteristics of enclosing rocks.

Materials and results of research. The research was based on the data of surveying regularities in changes of border mass strain-stress behaviour and amounted to the determining of expected displacement of natural mine working contour.

Finite element method was used to simulate single rectangular section mine working with such linear dimensions as: 6 m width, 3 m height. The mine working was located in the center of homogeneous mass (with the dimensions of 50×50 m). Simulation had three stages.

Papers [7, 8] contain schemes to determine affected areas b_a of single anchor and calculation model to study its influence upon border rock mass.

Stage I. Ten variants were offered. Variant 1 is a mine working without support. Variants 2 to 10 are: mine workings have supports in the form of single anchor set in the roof center.

Following physical and mechanical parameters of rock mass were involved: elastic modulus E=7950 MPa, Poisson's constant μ=0.23, ultimate compressive strength R_c=30 MPa, tensile strength R_p=3.0 MPa, and rock density γ=2.5 t/m^3. Linear elements were used to simulate polymer glass anchoring. Anchor parameters are as follows: length is 3 m, elastic modulus is $2\cdot10^6$ MPa, and Poisson's constant is 0.35. Mine working depth is 400 m that corresponds to rock pressure of 10 MPa. While simulating, there were some changes in variants 2-10 when anchor length changes within the ranges of l_a=1-5 m.

Fig. 1 demonstrates a curve of dependence of changes in single anchor affected areas b_a values on border rock mass upon its length l_a.

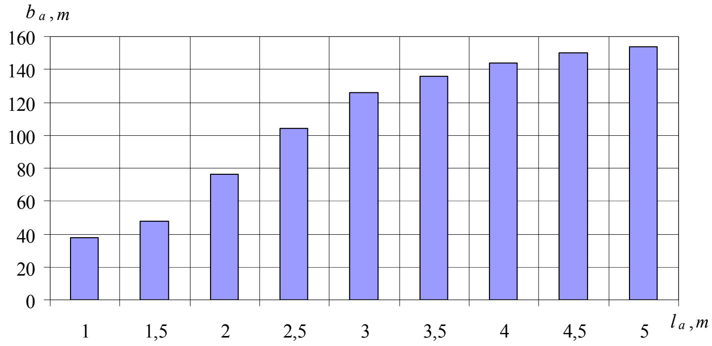

Fig. 1. Diagram of dependence of rational value of effect area changes on border rock mass of single anchor upon its length

Comparison of the results helps to make following conclusions:

When anchor is set, an area of mine working roof rock related to it;

Area of rock displacement maximum is divided into two parts shifting from the center to the working wall;

Displacements within anchor area are by 6-30% less then maximum ones on the contour;

Dimensions of 2.5 m single anchor effect area were 1.25 m while its rational length is 1.04 m.

While changing anchor length l_a from 1 m to 5 m dimensions of rational effect area of single anchor b_a increases from 38 cm up to 154 cm to be described by fourth-order polynomial linear connection, i.e. b_a=0.1568 l_a^4-3.3557 l_a^3+22.517 l_a^2-33.637 l_a+51.556 (Fig. 1);

Anchor of about 3 m long has main effect considering displacement reduction on mine working contour; in this context 76% of effect area is represented;

Increase of effect area of single anchor when its length varies from 3 m to 5 m is 24% only.

Stage II. The research simulated 3 situations 7 variants each, when mine working is fixed with single anchor (of 2, 2.5, and 3 m long) set in the roof center. Working depth is 1000 m corresponding to rock pressure of 25 MPa. While simulating, physical and mechanical parameters of rock mass were changed (R_c=20-80 MPa, R_p=2-8 MPa, E=7350-22769 MPa, μ=0.21-0.23).

The results were used to construct a diagram of dependence of change in rational value of effect area b_a of single anchor on border rock mass at different physical and mechanical rock parameters (Fig. 2).

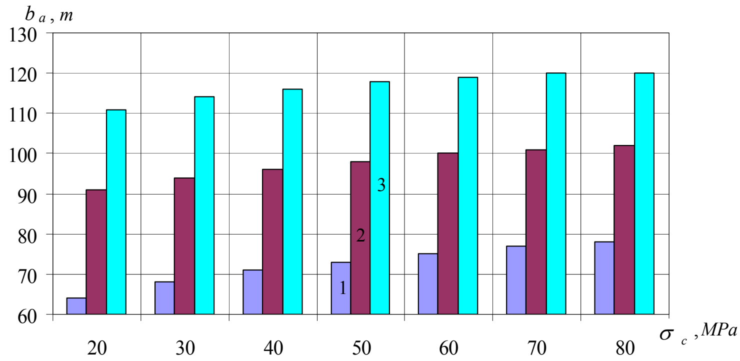

Fig. 2. Diagram of dependence of change in rational value of effect area of single anchor on border rock mass at different physical and mechanical rock parameters: 1 – l_a = 2 m, 2 – l_a = 2.5 m and 3 – l_a = 3 m

While analyzing the results, following conclusions can be made:

Displacement within the anchor area is by 8…25% less than maximum ones on contour depending on physical and mechanical rock parameters;

Maximum displacements within the mine working contour decrease from 76.9 down to 19.9 cm when R_c parameter changes from 20 up to 80 MPa;

If the same condition is taken into account, then rational value of effect area of single anchor b_a increases. If l_a = 2 m (1), then it increases from 64 to 78 cm (21.9%) being described by the power dependence: $y = 63.618x^{0.1031}$; if l_a = 2.5 m (2), then it increases from 91 to 102 cm (12,1%) being described by the power dependence: $y = 90.494x^{0.06}$; if l_a = 3 m (3), then it increases from 111 to 120 cm (8.1%) being described by the power dependence: $y = 110.91x^{0.0426}$ (Fig. 2);

Changes in a value of single anchor effect area on border mass when R_c = 20…60 MPa made up 90%; further increase of rock mass strength properties has almost no influence upon the value of parameter b_a (Fig. 2).

Stage III. The research provides 4 situation 7 variants each: mine working is fixed with single anchor (of 2, 2.5, and 3 m long) set in the roof center. Following physical and mechanical rock mass parameters were used: elastic modulus E=7950 MPa, Poisson’s constant μ=0,23, ultimate compressive strength R_c = 30 MPa, tensile strength R_p=3,0 MPa, and rock density γ = 2,5 t/m^3. While simulating mine working depth was measured within H = 400-1000 m range. The calculations applied software product developed by the Department of Construction and Geomechanics of the National Mining University and a pack of Phase-2 applications.

Graph of dependence of change in rational value of single action effect area b_a of constant length on border mass upon mine working depth under conditions when physical and mechanical rock parameters are constant (Fig. 3).

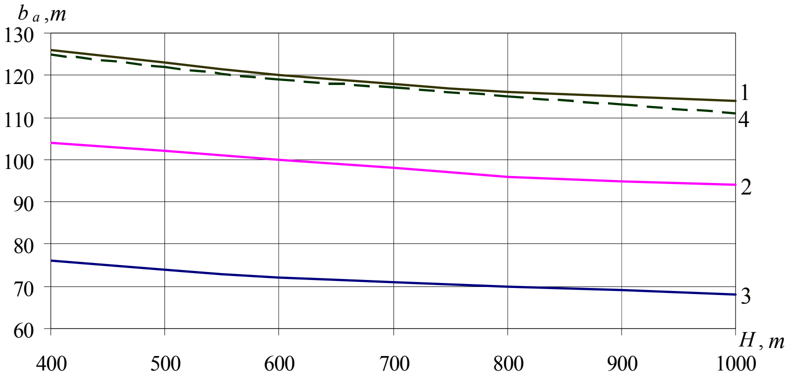

Fig. 3. Dependence of change in rational value of single action effect area b_a of constant length on border mass upon mine working depth: 1, 2, 3 – results according to software product of the Department of Construction and Geomechanics (l_a = 3, 2.5 and 2 m); 4 – results according to the pack of Phase-2 applications (l_a = 3 m)

Comparison of the results helps to make following conclusions:

Rock displacements within anchor area are by 20…30% less than maximum ones on contour irrespective of the depth;

Maximum rock displacements within mine working contour increases from 19.2 to 56.2 cm while within anchor area it increases from 13.5 to 45.3 cm (l_a = 2, 2.5 and 3 m); it occurs when the mine working depth increases from 400 m to 1000 m;

When mine working depth varies within 400…1000 m then rational area of single anchor effect b_a decreases as follows: if l_a=3 *m* (curve 1), then it decreases from 126 to 114 cm (9,5 %) being described by the power dependence: $y = 246.33x^{-0.1121}$ and (curve 4) from 125 to 111 cm (11.2 %) being described by the power dependence: $y=270.17x^{-0.1282}$; if l_a = 2.5 m (curve 2), then it decreases from 104 to 94 cm (9.6%) being described by the power dependence: $y = 207.8x^{-0.1149}$; if l_a = 2 *m* (curve 3), then it decreases from 76 to 68 cm (10.5%) being described by the power dependence: $y=155.24x^{-0.1194}$ (Fig. 3);

As Fig.3 shows changes of single anchor effect area obtained by using different program software are similar (curves 1 and 4) and values divergence is 1-4%;

At changing mine working depth from 400 to 850 m rational area of single anchor effect b_a is 92%, if change is from 850 to 1000 m - it is 8%; moreover beginning from the depth of 850 m and more situation simulation shows on graph that the curves becomes flatter, so value of single anchor effect area experiences unessential changes (Fig. 3).

Conclusions. Rational area of single anchor effect set in the roof center of a mine working located in homogeneous rock mass is 38-154 cm at its length changes within 1-5 m. Rational area of single anchor effect is almost 3.0 m; the range of its effect area is 126 cm. If l_a = 3 m then R_c and H changes influence effect area as follows: from 20 to 80 MPa - 111-20 cm and from 400 to 1000 m - 126-114 cm correspondingly.

Further research will be focused on studying effect of single anchor in heterogeneous border rock mass.

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