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GEOMECHANICAL PRINCIPLES FOR DESIGNING CROSSCUTS IN STEEP SEDIMENTARY ROCK MASS

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ГЕОМЕХАНИЧЕСКИЕ ОСНОВЫ ПРОЕКТИРОВАНИЯ КВЕРШЛАГОВ, РАСПОЛОЖЕННЫХ В КРУТОПАДАЮЩЕМ МАССИВЕ ОСАДОЧНИХ ГОРНЫХ ПОРОД

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ГЕОМЕХАНІЧНІ ОСНОВИ ПРОЕКТУВАННЯ КВЕРШЛАГІВ, РОЗТАШОВАНИХ У КРУТОПАДАЮЧОМУ МАСИВІ ОСАДОЧНИХ ГІРНИЧИХ ПОРІД

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Annotation. In the context of mines with steep seams, it is of great importance to solve a problem of accelerating the rates of new horizon preparation by reducing amount of mining operations and applying advanced supports in the capital crosscuts (roof-bolting, shotcreting, and combined supports). In order to substantiate area of the advanced support application in the crosscuts, an integrated mine research was performed, industry-based experiments were carried out, and typical project of consolidating the mine roadways with the help of the shotcrete supports was developed. Analysis of rock pressure manifestations included the following: survey of the mine roadways and over-support areas; mounting of line and deep gauge stations; rock fracture characterization by the cores drilled out from the rock mass; statistical data processing and substantiation of the support parameters by economic-probabilistic methods; development of practical recommendations; and industry-based experiments for verifying the solutions obtained. The following regularities were determined experimentally, which concerned behaviour of rock pressure parameters in the crosscuts driven in the steep stratified rock mass: rock displacements within the contour and in the depth of zone with non-elastic deformations; thicknesses of broken and displaced rocks; inrush heights in the rocks broken by blast and fallen on the bearing support. A new phenomenon was identified: disintegration of rock mass being stable in the contour of the mine roadway cavity. It was determined that rock inrush from area between the anchors was a random value with density distributed by the Laplace law; signs of extremely unstable rocks were defined. Range of use and parameters of the roof-bolting, shotcreting, metal frame, and combined supports were substantiated by the economic-probabilistic approach. The performed research became a basis for development of a standard project for the mine working consolidation by the advanced supports; the supports were tested at industrial scale; and schemes of support setting in the crosscuts were reviewed. The research makes it possible to reduce by 30% expenditures connected with a new mine horizon opening.

Keywords: geo-mechanics, design, crosscut, steep rock massive, sedimentary rocks

1. Introduction

In the context of mines with steeply dipping seams, it is of current interest to solve a problem of the accelerated preparation of new level by means of the decreased amount of mining and application of the advanced supports within capital crosscuts(i.e. roof-bolting, shotcreting, and combined) [1,4].

To substantiate application area of the advanced supports within crosscuts, integrated mine research has been performed, industry-based experiments have been carried out, and typical design to support mine workings with the help of shotcrete supports have been developed.

2. Methods

Analysis of rock pressure manifestations has included the following: survey of mine workings and over-support areas; mounting of line gauge stations and deep ones; rock fracture characterisation on the cores drilled out of the rock mass; statistical data processing and substantiation of the support parameters using economic and probabilistic methods; development of practical recommendations, and industry-based experiments to verify the solutions which have been obtined.

3. The results which have been obtained and their discussions

3.1. Observations

The Following scientific facts have been established as a result of the survey of crosscuts and over-support areas: generally, rock border of crosscuts is stable; maintenance of crosscuts is repair-free; there are cavities all over the area behind the support of mine workings; support takes up load from the weight of back-filling rock layer. The exception is represented by the crosscut areas crossing the layers of unstable rocks including: lumpy rock; partings of dissected coal seams; seams prone to inrushing and shales within the contact points with water-bearing limestones and sandstones.

Certain over-support areas are characterized by rock inrushes onto the support.

Rock heaving in permanent crosscuts is not observed.

3.2. Displacement of rock border

Displacement of stratified rock border is insignificant (up to 25 mm) being less than the gap between support and rock border. Displacing rocks are not involved in the system of forces transmitting pressure to the support. Displacement of solid rocks is not more than 5 mm; within distortion unstable rock crossing, they reach 300 mm.

3.3.Thickness of the zone of inelastic deformations

Observations in terms of deep measuring stations have helped to determine that thickness of the zone of inelastic deformations within solid and stratified rocks is not more than 1.5 m.

Within the points of unstable rock crossing, thickness of the zone of inelastic deformations is from 3 m to 5 m.

3.4. Regularitiesof blasting rock breaking

There is the alternation of the zones of broken and unbroken rocks being at equal distance from the mine workings border behind the crosscuts border [2]. The determined regularity is proved by independent studies and developed as the effect of rock disintegration [3,5] as a result of not blasting but geomechanical forces.

Thickness of the first zone of technological fracturing which is found immediately beyond the crosscuts border, depends on the rock tensile strength in uniaxial compression (Fig. 1):

$$B_\tau = \frac{1}{a + bf}$$

where f is coefficient of rock strength according to the scale by M.M. Protodyakonov a = 0.38, b = 0.058 are empirical coefficients.

The time factor and cross-section area of crosscuts crossing stratified and solid rocks have no considerable effect upon the thickness of first fractured zone boom.

The density of the fracture amount decreases along with the distance of rock mass from the mine workings border. Two areas of the first fractured zone are characteristic ones: active and passive. The thickness of the area of active fissuring is ~80 % of total thickness of the fractured zone.

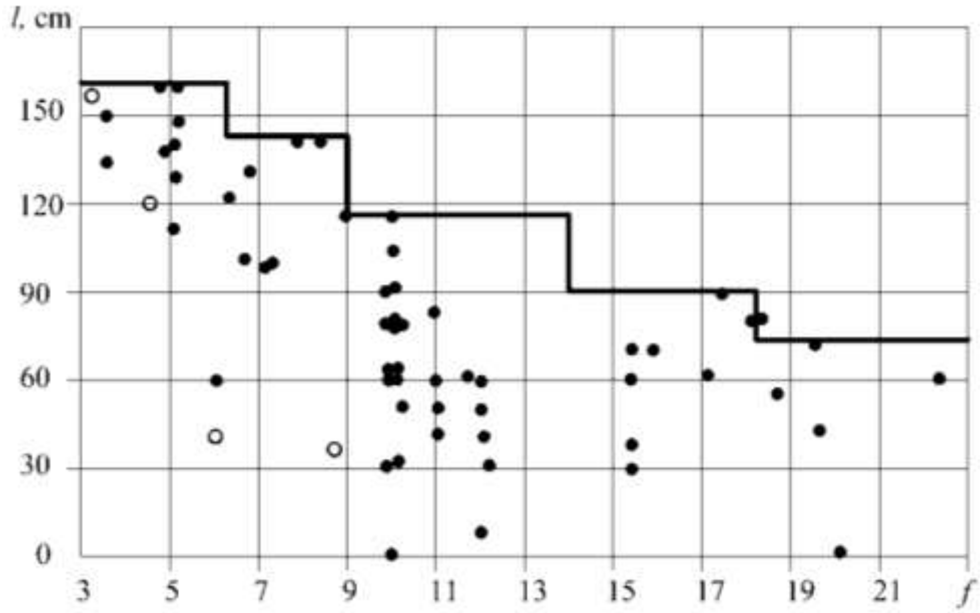

Figure1 - The influence of the rock-hardness ratio on the size of the fracture zone around the drifts

3.5. The Regularities of the inrush formation

The rock inrush height onto the supports of mine workings is not more than the thickness of the first zone of technological fissility.

In terms of roof-bolted crosscuts, height of rock inrush from inter-bolted area is a random value with the density of distribution which follows the hyperbolic law.

The maximum height of rock inrush from inter-bolted area is equal to the half of the distance between bolts.

3.6. A differentiated approach to the selection of support type

A differentiated approach to substantiate support types and parameters has been developed on the basis of typification of natural conditions in crosscuts. In general, four groups of controlling crosscuts conditionshavebeenemphasized.

Group one includes the crosscuts areas crossing solid sandstones and characterized by insignificant (up to 5 mm) rock border displacements. Group two involves crosscuts crossing layers of thick (m≥10 m) stratified rocks (sandstones, aleurolites, and argillites). Rock border displacements under such conditions are 5-25 mm. Group three includes areas of crosscuts at crossing areas of coal seams being not prone to inrushing and stratified rocks as well as a part of alternating layers of small-thickness rocks (m≤3...4 m) with different strength. Under such conditions, rock border displacement is not more than 50-100 mm. In third group of conditions for supports, we can observe destruction of shotcrete and combined(bolts and shotcrete) supports. At the same time, combined support (shotcrete and light-weight metal frames) provides repair-free maintenance of mine workings Group four involves crosscuts areas crossing block and lumpy rock structures, water-saturated argillaceous shales, argillites within the contacts with water-bearing limestones or sandstones, partings of the zones of intersected coal seams, small-thickness argillites occurring within the immediate roof (floor) of coal seams prone to inrushing. Rock border displacements under such conditions are up to 200-300 mm.

A comparative geological section in terms of mines of Central Donbas region has been developed indicating zones of rocks prone to caving. In this context, it has been defined that total thickness of rocks prone to caving (group four) is relatively small being not more than 7 % of total coal-bearing thickness.

Table 1 represents recommended supports for crosscuts constructed in steeply dipping rock mass.

3.7.Substantiating support parameters

The results of mine experimental studies and generalized practice-based data have become the basis to substantiate geomechanical parameters of supports for permanent crosscuts.

Basing upon the data on thickness of fissility zones, active length of bolts has been substantiated (Table 2).

Table 1 -Recommendedsupportsforcrosscuts disclosed steep-dipping rocks.

Group of support conditions	Displacements of rock border of mine workings, mm	Area of crosscut cross-section, m^2	Rational support
I	up to5	up to 50	Shotcrete(δ = 30 mm) or frame-arch made of light-weight profiles with metal mesh
II	5-25	up to50	Combined obolt sands hot crete (δ = 30 mm) frame-arch made of light-weight profiles with metal mesh
III	up to100	up to50	Frame-arch
IV	up to200	up to20; 20-50	Frame-arch; the same with backfilling of cavities behind the support

Table 2 -Active length of bolts.

Coefficient of rock strength accordingto the scale by M.M. Protodyakonov	2-3	3-6	7-9	10-14	15-18	18
Length of the active share of a bolt, m	1.8	1.6	1.4	1.2	0.9	0.7

Thickness of shot create layer and density of bolting have been determined by means of technical and economic modeling. The problem was solved in terms of two types of modeling: determinate and probabilistic.

The following results have been obtained for combined support of bolts and shotcrete:

a) in terms of determinate modeling, optima lparameters are as follows: shot create layer thickness is δ = 0.05 m and distance between bolts is $a \approx 1.0$ m;

b) in terms of probabilistic modeling, optimal parameters are as follows: shot create layer thickness is δ = 0.003m and distance between bolts is up to 1.5 m;

Parameters of metal arch support. It is not expedient to apply metal flexible supports in permanent crosscuts since rock border displacement is less than a technological gap between the borders of support and rock cavity. Rigid operating mode of support is optimal in this case. Support load on frames should be determined based on the condition $G \geq Q$, where G is bearing capacity of the support, kN; Q is weight of rocks broken by blasting, kN.

3.8. Substantiating crosscut geometry

While studying crosscuts being operated without support, it has been determined that actual height of cross-section archsis not more than 1/6 of their width, i.e. almost twice less than it is recommended by standard design with concrete support. Decrease in arch height has made it possible to reduce rock excavation volume by 15-20%.

3.9. Selecting type of shaft in sets

The fact that rock pressure parameters do not depend upon the cross-section area of crosscuts has allowed evaluating the expediency to design station-type shaft insets basing upon the mine workings of increased cross-section. Structural comparative analysis has helped define that station-type shaft insets are more economic than the ones based on standard cross-sections of mine workings by 30-35%.

3.10 Optimal elements of crosscuts

Cross-sectional shape. The optimal shape of cross drift is a half-circle under the terms of minimizing the cost of breaking the rock and fastening the cross-section of a given area, set at the permissible air velocity.

The best is a cross drift with a vault box-shaped with their width adopted according to the conditions of transport.

Distance between parallel crosscuts. Crosscuts do not have a mutual influence on the stability of rock exposures when the distance between their contours is 8-10 m.

The results of the studies have been implemented into the projects of opening and preparation of new levels of Central Donbas region.

Conclusions

1. The basic regularities of changes in geomechanical parameters of rock-support systems (displacements, thickness of the breaking zones, rock caving, rock inrush formation) for crosscuts driven in steeply dipping rock mass have been specified;

2. It has been defined that crosscuts driven across the strike of stratified sedimentary rocks are characterized by increased stability. They are expedient to be supported by advanced supports: bolting, shotcreting, and light-weight rigid H-beam support.

3. Shotcrete thickness should be specified in the context of the conditions of rock protection weathering ($\delta \approx 3$ cm) while parameters of bolting and metal frame

supports should be taken basing upon the thickness of the rock broken with blasting beyond the mine working border.

4. The application of advanced supports helps to reduce amounts of permanent crosscuts by 15-20 %.

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Анотація. Для шахт з крутим падінням пластів актуальним є рішення проблеми прискорення підготовки нових горизонтів - шляхом зменшення об'ємів гірських робіт і вживання прогресивних кріплень у капітальних квершлагах (анкерного, набризкбетонного і комбінованого). Для обгрунтовування області вживання прогресивних кріплень у квершлагах виконано комплексні шахтні дослідження, проведено дослідно-промислову перевірку і розроблено типовий проект кріплення виробок набризк-бетонним кріпленням. Дослідження проявів гірського тиску включали: обстеження гірничих виробок і надкріпних просторів, встановлення контурних і глибинних вимірних станцій, дослідження тріщинуватості порід по кернах, вибурюваних з породного масиву; статистичну обробку даних і обгрунтовування параметрів кріплень методами економіко-вірогідності, розробку практичних рекомендацій і дослідно-промислову перевірку одержаних рішень. Експериментально встановлено закономірності зміни параметрів гірського тиску у квершлагах, пройдених у крутопадаючому шаруватому породному масиві: зсувів порід на контурі і в глибині зони непружних деформацій; товщини зруйнованих порід і порід, що зміщувалися; висот вивалів у породах, зруйнованих вибухом і обрушених на підпірне кріплення. Встановлено нове явище – дезінтеграция порідного масиву, стійкого на контурі порожнини гірської виробки. Встановлено, що вивал породи з міжанкерного простору є випадковою величиною, з густиною розподілу за законом Лапласа, і ідентифіковано ознаки особливо нестійких порід. Обгрунтовано області використання і параметри анкерного, набризкбетонного, металевою рамою і комбінованого кріплення, на основі підходу економіко-вірогідності. На підставі виконаних досліджень розроблено типовий проект кріплення виробок прогресивними кріпленнями, проведено дослідно-промислову перевірку кріплень і переглянуто проекти кріплення капітальних квершлагів. Дослідження забезпечує зниження витрат на розкриття нового горизонту шахти до 30 %.

Ключові слова: геомеханіка, проектування, квершлаг, крутопадаючий масив, осадкові гірські породи.

Аннотация. Для шахт с крутым падением пластов актуально решение проблемы ускорения подготовки новых горизонтов - путем уменьшения объемов горных работ и применения прогрессивных крепей в капитальных квершлагах (анкерной, набрызгбетонной и комбинированной). Для обоснования области применения прогрессивных крепей в квершлагах выполнены комплексные шахтные исследования, проведена опытно-промышленная проверка и разработан типовой проект крепления выработок набрызгбетонной крепью. Исследования проявлений горного давления включали: обследование горных выработок и надкрепных пространств, установку контурных и глубинных замерных станций, исследование трещиноватости пород по кернам, выбуриваемым из породного массива; статистическую обработку данных и обоснование параметров крепей экономико-вероятностными методами, разработку практических рекомендаций и опытно-промышленную проверку полученных решений. Экспериментально установлены закономерности изменения параметров горного давления в квершлагах, пройденных в крутопадающем слоистом породном массиве: смещений пород на контуре и в глубине зоны неупругих деформаций; толщин разрушенных и смещающихся пород; высот вывалов в породах, разрушенных взрывом и обрушенных на подпорную крепь. Установлено новое явление – дезинтеграция породного массива, устойчивого на контуре полости горной выработки. Установлено, что вывал породы из междуанкерного пространства есть случайная величина, с плотностью распределения по закону Лапласса, и идентифицированы признаки особо неустойчивых пород. Обоснованы области применения и параметры анкерной, набрызгбетонной, металлической рамой и комбинированной крепей, на основе экономно-вероятностного подхода. На основании выполненных исследований, разработан типовой проект крепления выработок прогрессивными крепями, проведена опытно-промышленная проверка крепей и пересмотрены проекты крепления капитальных квершлагов. Исследование обеспечивает снижение затрат на вскрытие нового горизонта шахты до 30 %.

Ключевые слова: геомеханика, проектирование, квершлаг, крутопадающий массив, осадочные горные породы

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