Research of segregation zones of marginal rocks for prediction the rigidity of rocks roof and sides of mine workings

Alexander Vorobev

Doctor of Technical Sciences, Professor
Head of the Department of Petroleum Geology, Mining, Oil and Gas Business
Peoples Friendship University of Russia, Moscow, Russian Federation
Ministry of energy RF, Pro-rector for international relations
Institute of improvement of professional skill of executives and specialists of fuel and energy complex
fogel_al@mail.ru

Vladimir Demin

Doctor of Technical Sciences, Professor
Department of "Mineral deposits development"
Karaganda State Technical University, Karaganda, Kazakhstan
vladfdemin@mail.ru

Rustam Khodzhaev

Director, Doctor of Technical Sciences
Research and Engineering Center «GeoMark»,
Karaganda, Kazakhstan

Tatiana Demina

Candidate of Technical Sciences, associate professor
Department of Mine ecology and labor protection,
Karaganda State Technical University
Karaganda, Kazakhstan
vladfdemin@mail.ru

Abstract
The article presents the results of an experimental remote control of assessment of stress-strain state of rock mass destroying the roof and sides of working displacements by deformation monitoring instruments, which has carried out a visual control over the segregations in the massif as well as the massif displacement and segregation in the marginal rocks of mine working have been estimated quantitatively. The authors conducted production monitoring of mine working rigidity during different periods of service life and application in the mines of the Karaganda coal basin fixed by different types of supports. Modes of operation of the combined support with metal-frame support with rigid anchors were investigated. The parameters of deformation processes close to the working at their location in the impact area of second working were defined. On the basis of statistical processing of experimental data, the regularities of deformation processes and empirical dependences on the influencing factors were determined. The analytical modeling for prediction the stress-strain state of technogenic space for the establishment of durability (the time to failure and evaluation of sustainability in the excavation working depending on the depth of the mine working with the change of controllability of enclosing rocks) was carried out. The results of the analytical and experimental studies have demonstrated their relative convergence with respect to the deformation characteristics. It is advisable to use a roof bolting for a more complete use of the bearing capacity of the combined support and increase the rigidity of mine working in bearing pressure zone. Anchors bind individual lowly cohesive rock layers into a single load-carrying structure of composite plate, thereby increasing coupling and friction between the layers. Additional friction occurs due to anchors tension between the layers of rocks. At the same time, the rigidity of the composite plate tightened by anchors across the layers approaches to the rigidity of the monolithic rock mass.
Carried out research of technological segregation zones in marginal rocks for prediction the rigidity of rock top and sides of mine working allowed to establish the degree of influence of mining and technological factors on the effectiveness of the rock anchor application in the excavation working.
Key words: ROCK ANCHOR, SEGREGATION, ROCKS, EFFICIENCY, DEVELOPMENT EXCAVATION, FORECAST, ROCK RIGIDITY

Introduction

In the Karaganda basin, a combined lining of metal arch and anchor constructions combination has wide application. Comparative studies of rock pressure occurrence in mines with different types of fixing have allowed establishing the nature of their operational efficiency. At the same time, deformation of working with combined anchor-frame supports is 3-4 times less than with metal-frame support.

Lining design should prevent the growth of fracture zones (inelastic deformations) of marginal part of the rock walls when their outcrop. At the same time, according to durability the fracture zones in edge part of the working at various time intervals after outcrop are determined [1-4].

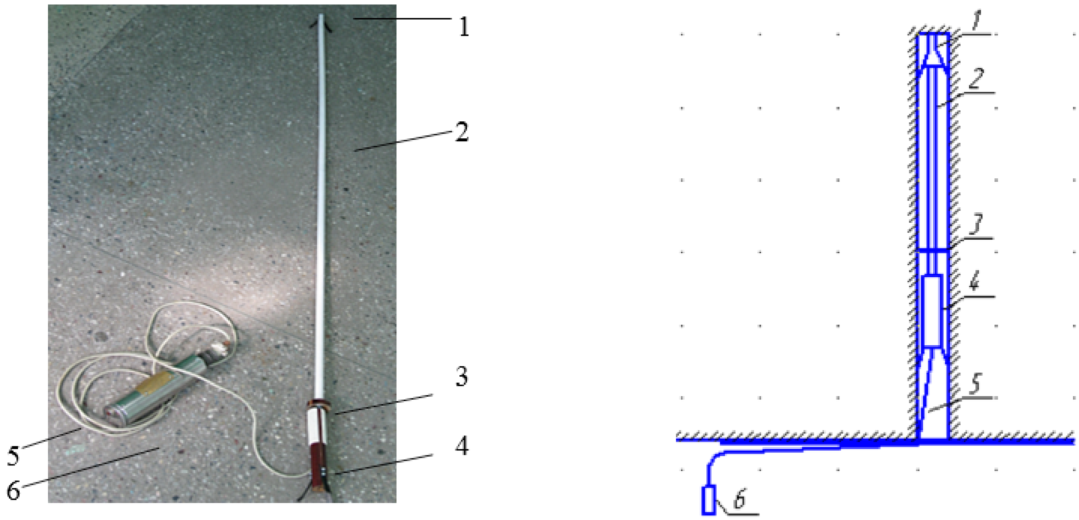
Research of the method justifying the application of roof bolting, which affects the development of fracture zones in the marginal rocks by coupling and strengthening them within the initial segregation zones formed outside the zone of influence of second working to create a safety bridge distributing the pressure on the springing block playing later the role of the surcharge distributor of displaced overlying rocks in pressure bearing zone has been performed.

Defining the area of the initial rocks segregation allows predicting the rocks rigidity and cave of roof and sides of working for the purpose of selection the rational parameters of their conducting.

Discussion of the problem

In order to determine segregation of rocks, remote control over the evaluation of the stress-strain state of rock massifs destroying the roof and sides displacements of working by deformation control devices KDM-1 and KDM-2 (All-Union Scientific Research Institute of Mining Geomechanics and Mine Surveying construction, Russia) was performed. A visual inspection of the segregations in the massif was carried out using the first device, and with the device KDM-2 massif displacement and segregation in the roof rocks was evaluated quantitatively (Figure 1). The displacements were measured in the marginal rocks on the belt entry $71k_{10}$-v of “Saransk” mine of Karaganda coal basin at a depth of 450 m. In order to control, 3 holes were drilled (center and two at an angle of 45^o to it) in the working roof (Figure 2).

The immediate roof bed is represented by medium rigid argillites with power ranging from 1 to 5 m and strength of 15-20MPa with the distance between the cracks of 0.5 m and the main difficult roof with power of 24-30 MPa made of sandstone with strength of 65-70 MPa.



a) b)

Figure 1. General view (a) and scheme of measuring (b) by control devices of massif deformations KDM-1 and KDM - 2

1, 2 – base grade peg and its rod; 3- retainer washer; 4 – sensor; 5 – connecting cable; 6 –KDM-2 device

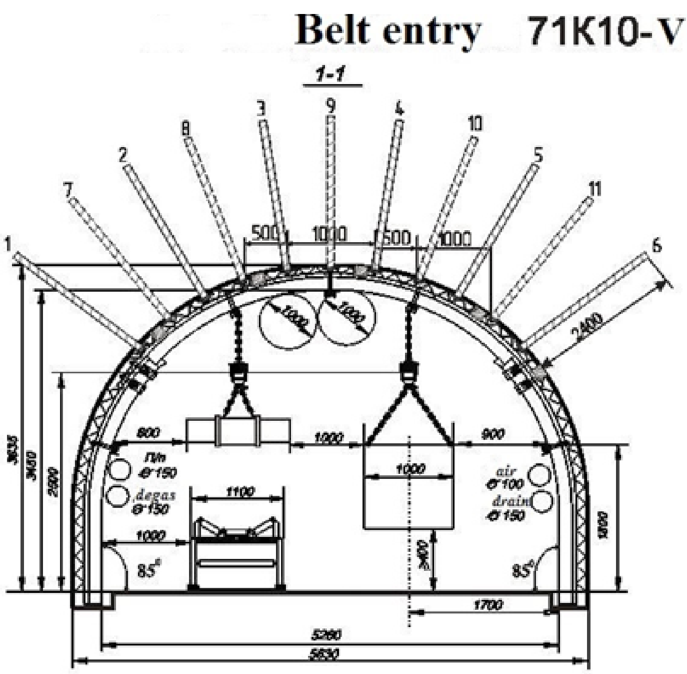
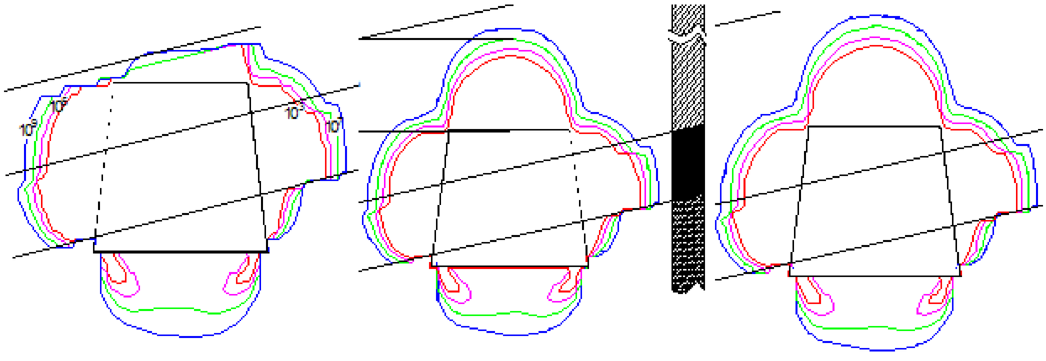


Figure 2. - Scheme of working fixing with combined lining

Outside the affect zone of second works, first segregation contour occurred after 20 minutes at a distance from the working of 1.6 m, after 25 days at a distance of 1.8 m and after 3 months - 2.2 m. Evaluation of the influence degree of roof rocks controllability on the deformability of the rock massif has shown that when the light- and medium-controlled rocks in the roof, soil and space of the side walls, the cracks planes are formed at a distance of 2.5 - 2.9 m from the entry contour and when hard controlled rocks – in the roof directly above the mine working.

Depending on the controllability of enclosing rocks, the degree of crack formation intensity was considered at trapezoidal shape of working cross-section. The most remote cracking extends from all sides of the working at a distance from the contour of 2.4 - 2.5 m and even less remote (0.4 - 0.5 m) near the side racks in soil near the mine working with light- and medium-controlled lining. In case of difficult-to-control roof, the cracks in the roof are close to the working and they are located at a distance from the working section, which does not exceed 0.5 m (Figure 3).



a) b) c)

Figure 3. Influence of controllability of the roof rocks on the deformability of the rock massif a, b, c - with light- and medium and difficult to control roof respectively

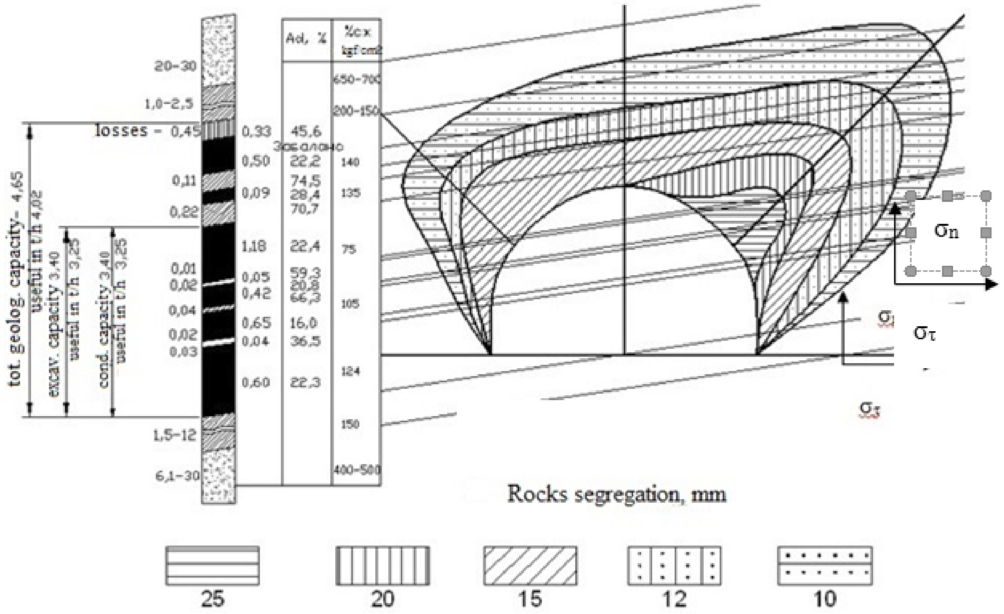


Figure 4. Segregation zones of the marginal rocks massif of the belt entry 71k$_{10}$-v of "Saransk" mine

The most dangerous are tensile stresses perpendicular to bedding and exceeding tensile strength on the contacts and causing detachment of rocks with a separation of beds from each other and then their collapse. The process of rocks segregation occurs under the action of shear stresses directed along the bedding planes, which cause beds sliding. The value of coupling on the contact layer sites folded by carbonaceous layer in case of argillite was 0.1, while the sandstone - 0.4 MPa.

Figure 4 shows that the three segregated soft rock contact has been formed. Processing of the experimental data allowed obtaining the ratio of fracture modulus from the layer thickness and its tensile strength (Figure 5).

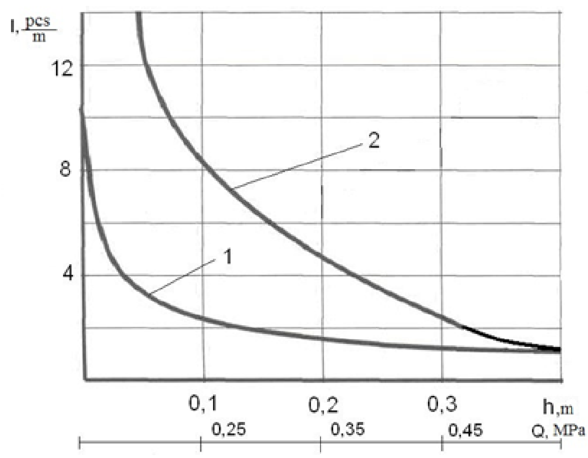
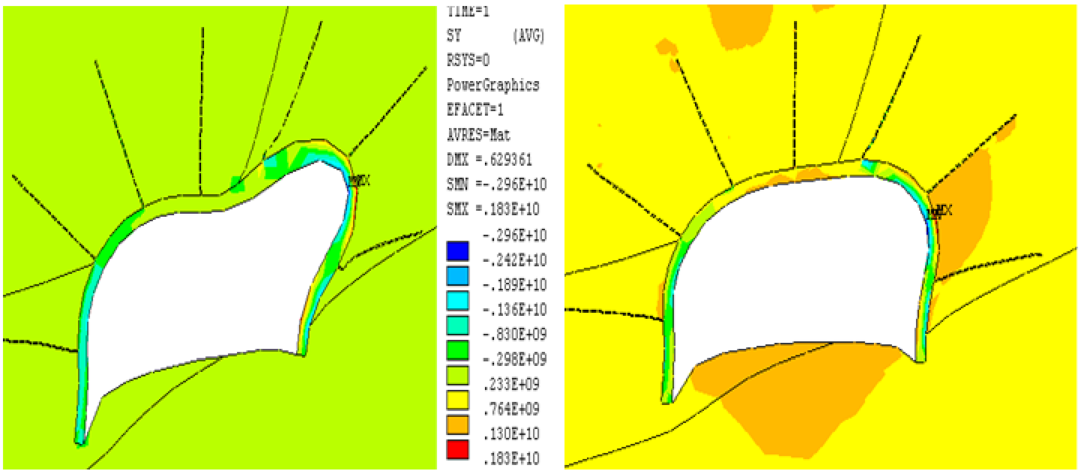


Figure 5. Ratio of fracture modulus (*I*) from layer thickness (*h* - 1) and tensile strength (Q_c - 2)



a) b)

Figure 6. Deformation pictures of areas with equal longitudinal strains in ventilation working with combined roof support (metal frame and anchor)

a – r_g=1.5; b –r_g=2.0

The analytical modeling of the working condition was carried out by the finite element method for the conditions specified above [1, 2]. Figure 6 shows the deformation pictures of areas with equal longitudinal stresses in the ventilation working with combined roof supports (metal frame and anchor from the top to the rise of layer developed space is located) where r_g – gain ratio.

In the mine working fixed with combined anchor (in a staggered pattern) and metal frame roof supports (Figure 6a) without support gain the longitudinal stresses were 300-830 MPa, and in the influence zone of second works with gain roof support (with gain ratio r_g= 1.5; 1.85; 2.0) despite the growth of rock pressure they amounted to 400-600 MPa (Figure 6b), thus achieving the rigidity of working contours. In this case, the load on working using roof bolting is 1.15 times smaller.

In the zone of second working, the vertical component of the pressure is increased and due to surcharge of overlying rocks mounting bases and their segregation, conditional inelastic deformation zones with displacement of rocks in the roof of the working on 1.2-1.3 m are also increased. The timely installation of reinforcing lining will allow reducing the marginal rocks displacement and maintaining the working in operational state.

In the considered working, for comparison the operation modes of combined lining with metal frame supports and rigid anchors in the zone of influence of second working were studied (Table 1).

Table 1. Rigidity of the contours of the belt entry 71k$_{10}$-v of "Saransk" mine depending on the technological parameters of fixing

A_b, kN	T_g	L_a, m	D_i , pcs/m^2	P_t, kPA	C_r, mm	P_m, m	G_c
Anchors without yield							
12	1	1.8	1.0	70	590	0.9	0.1
12	1	2.0	0.93	100	540	0.91	0.1
12	1	2.2	1.2	155	460	0.92	0.5
15	1	2.0	0.9	170	435	0.93	0.6
15	2	2.2	1.2	190	390	0.95	0.85
15	2	2.4	1.28	375	260	0.3	0.95

Where : A_b – bearing capacity of roof bolting, t; T_g – the number of rows of gain lining of centre posts; L_a – anchor length, m; D_i – density of anchors installation, anchor /m^2; P_t – total resistance of the frame, anchor and gain lining;
C_r – roof displacement, mm; P_m – massif segregation in the roof bolting installation zone, m.

Statistical processing of the experimental results during the construction of adjustable anchors with stable roof rocks in the zone of influence of second works with gain lining (racks for profiles) allowed to determine the empirical dependence of the working rigidity from the influencing factors (with a correlation coefficient R^2=0.99):

$$G_c=4.84 - 0.08A_b - 0.08T_g - 0.77L_a + 0.72D_i - 0,01P_t - 0,04C_r - 0,51P_m. \quad (1)$$

According to Student's test dependence of G_c from A_b, D_i, C_r is significant, T_g and L_a - insignificant and P_t and P_m – minimal.

Directly under the lava in bearing pressure zone gain lining from 1-2 rows of wedge-type or hydraulic props for two-lines of profiles were fixed. Under these conditions an increase in design strength of roof bolting from 60 to 140 kPa (kN/m^2). It allows reducing the segregation of roof rocks from 0.45 to 0.3 m (at 1.5 times).

When a small number of segregated contacts (up to three pieces) of soft rocks to ensure a satisfactory state of the roof rocks the design resistance of roof bolting should be 140-200 kPa at a length of anchors up to 2.4 m. The tests on the "Saransk" mine have established that when roof is stable (rocks strength to uniaxial compression R_c is more than 60 - 80 MPa), the installation density is 1 anchor/m^2 [5].

Further increase in length, tensile strength of roof bolting, its installation density in these conditions is technically and economically non-expedient as it does not lead to a marked decrease of roof rocks displacement and its condition only reduces the rate of mine workings.

Conclusion

The results of the analytical and experimental studies have shown their relative convergence according to deformation characteristics. Thus, for a more complete use of the bearing capacity of the combined lining and increasing the rigidity of production in bearing pressure zone it is advisable to use a roof bolting. Anchors bind individual little-connected rock layers into a single load-carrying structure of composite plate, thereby increasing coupling and friction between the layers. Additional friction occurs by tension the anchors between the layers of rocks. At the same time, the rigidity of the composite plates tightened across the layers by anchors is close to the rigidity of the monolithic rock mass.

Mine working with a combined anchor-frame support operates in three cycles: hard mode, yield mode with segregation and displacement of rock mass, mode of long-term rigidity with a constant bearing capacity due to head of the anchor and frame supports and rock blocks self-jamming.

References

1. Segerlind L. (1079) *Primenenie metoda konechnyih elementov* [Application of finite element method]. Moscow: Mir. 345p.
2. Gritsko G. I. (1995) Opredelenie napryazhenno-deformirovannogo sostoyaniya massiva vokrug protyazhennyih plastovyih vyirabotok eksperimentalno-analiticheskim metodom [Determination of stress-strain state of massif around extensive bedded working by experimental analytical method]. *Fiziko-tehnicheskie problemyi razrabotki poleznyih iskopaemyih* [Physical and technical problems of mineral development]. No.6. p.p. 45-49.
3. Kurlenya M. V., Baryshnikov V. D., Gakhova L. N. (2012) Razvitie eksperimentalno-analiticheskogo metoda otsenki ustoychivosti gornyih vyirabotok [The development of experimental and analytical method for estimating sustainability of mine working]. *Fiziko-tehnicheskie problemyi razrabotki poleznyih iskopaemyih* [Physical and technical problems of mineral development]. No.4. p.p. 56-60.
4. Tsidaev B. S., Golik V. I., Vorobyev A. E. (2001) Spetsialnyie sposobyi razrabotki slozhnostrukturnyih mestorozhdeniy [Special methods for development of complex deposits]. *Gornyiy informatsionno-analiticheskiy byulleten* [Mining informational and analytical bulletin]. No.9. p.p. 24-29.
5. Vorobyov A. E., Demin V. F., Nemova N. A. (2010) Innovatsionnaya tehnologiya vyiemki malomoschnyih i slozhnostrukturnyih ugolnyih plastov [Innovative excavation technology and low-capacity hard structural coal beds]. *Marksheyderiya i nedropolzovanie* [Mine Surveying and subsoil use]. No.2. p.p. 36-39.