DNIPRO UNIVERSITY of TECHNOLOGY 1899

Mining of Mineral Deposits
ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)
Journal homepage http://mining.in.ua
Volume 12 (2018), Issue 4, pp. 115-123

UDC 622.831.3 https://doi.org/10.15407/mining12.04.115

ANALYZING KINETICS OF DEFORMATION OF BOUNDARY ROCKS OF MINE WORKINGS

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ABSTRACT

Purpose is to analyze nature of rock deformation and to estimate experimentally state of mine workings being supported under the conditions of areas disturbed by coal mining.

Methods. The studies involved field instrumental observations within measuring points equipped with contour benchmarks. Express method was applied to determine height and width of the mine working; typical supported areas were designed; and photographs were taken. The research was conducted in a belt roadway and ventilation raise of western longwall 11 (c_{18} seam of MM "Pivdennodonbaske No. 1"), and in their connections with the longwall.

Findings. It has been determined that the longwall effect in the mine working, being supported repeatedly, is 80 – 60 m in front of a stope; vertical convergence within the area is more than 1 m; floor rise share is almost 76%; and share rate is more than 3 mm/day. It has been specified that local destruction of anchor fitting as well as almost 70% of deformation of frame support is observed within the zone of the longwall affect. It has been identified that potential inrush area from the belt roadway is between supports 3 and 9 of a face zone support; i.e. distance from the seam edge is more than 2.4 m. It has been proved that the use of rigid protective structures is not efficient in the context of soft floor rocks since the protective structures function like dies. Condition of the belt roadway, being constructed and supported behind the longwall, is satisfactory; boundary deformations are within the range of the support flexibility.

Originality. Regularities concerning deformation of boundaries of mine workings under the conditions of unstable wall rocks of c_{18} seam (MM "Pivdennodonbaske No. 1"), when the mine workings are being constructed and supported behind a stope to be used repeatedly for following longwall, have been determined. Regularities of the process when rocks are forced out into a mine working cavity remained after protective structure, being constructed along a mine working at the boundary of the worked-out area, have been identified as well as regularities of vertical convergence rocks within terminal sites of the longwall.

Practical implications. The findings can be used to develop measures and means for the stability of development mine workings under the conditions of unstable wall rocks and measures to prevent their fall within the tail longwall sites.

Keywords: *stability of mine workings, rock mass, deformations, supports, convergence*

1. INTRODUCTION

In the context of general complex of production processes, a problem concerning provision of operating state of mine workings, is one of the most topical involving the current state of mine facilities in Ukraine. Expenditures, connected with the construction of mine workings and their stability provision, are significant share of production expenditures. The component of expenditures increases along with mining deepening depending upon the increase in actual stresses and, as a result, deformation of enclosing rocks during extraction.

It is almost impossible to withstand rock displacement and formation of breaking zone while using traditional systems of support and systems of mine working protection since they prevent from active control over stress-strain state of support-protection structure-enclosing rock mass system (Sakhno, Malysheva, & Nefedov, 2014). The fact formulates new tasks for national mining science to develop new techniques for the support of mine workings and adaptation of current world-wide systems of support and protection to mining and geological conditions of Ukrainian coal mines.

Design of such systems and their implementation should involve peculiarities of deformation mechanism of boundary rocks as well as stress distribution within rock mass. Even if the known positive operation practices as for certain mine system are adopted, they cannot be applied without analysis of specific conditions. That can be confirmed by innovative for Ukraine plough systems, road heading machines, shearers, and systems of two-level support of mine workings applied by PJSC "DTEK Pavlohradvuhillia" in cooperation with ESR-Technology Company after geological, technologic, and economic peculiarities as well as systems to mine thin layers were analyzed (Vivcharenko, 2013; Petlovanyi, Lozynskyi, Saik, & Sai, 2018).

Thus, analysis of kinetics of boundary rock deformation within development mine workings to develop measures and means for their stability provision, relying upon the determined regularities of rock deformation, is a critical scientific and applied problem.

Basic regularities of deformation of boundary rocks of mine workings, being supported within a zone, affected by a stope, are common ones. However, implementation of new techniques to support and protect mine workings as well as constant exaggeration of geological and mining conditions motivates actuality of field studies. Such activities are common for Ukraine and the rest of the world (Shen, 2013; Khalymendyk, Brui, & Baryshnikov, 2014; Batchler, 2017; Waclawik et al., 2017; Esterhuizen, Gearhart, & Tulu, 2018).

Observations of boundary rock deformation within 165 mother entry where two-level anchoring in combination with frame support were carried out in "Stepova" mine (Halimendik, Brui, & Baryshnikov, 2013). The studies involved stations equipped with depth benchmarks in wells with 9 m depth. A step to set the benchmarks was 1 m. Geometric benchmark leveling was specific feature of the observations. It has been determined that within a zone, affected by mining, not only rock mass stratification is observed at a depth of down to 6 m but also overall subsidence at 6 – 9 m depth, i.e. 0.2 m subsidence across anchoring. Similar conclusion, concerning uniform subsidence of anchored formation, was obtained while observing depth benchmarks in Dobropilska mine (Rodzin, Sakhno, Ostrowski, & Sakhno, 2017). According to graphs in paper (Halimendik, Brui, & Baryshnikov, 2013), a zone affected by a stope (i.e. abutment zone) is almost 60 – 80 m. Pressing of strengthening support posts as well as legs of frame support into a floor has been stated.

The research, carried out in Qujiang coal mine (China) (Yu, Wang, Chen, & Du, 2015) at the depth of 886 m and under the conditions of soft rocks, has demonstrated similar results. Thus, judging by the graphs, a zone of a stope affect is almost 30 m. Total deformations in cross-section with the mine working are 0.6 m; their velocity is more than 4 mm/day at the distance of less than 25 m. Over 183 days, vertical convergence within mine workings being out of a stope affect was 0.766 m; horizontal one was 1.102 m. Deformation velocity was less than 3 mm/day. Nature of boundaries of the mine workings varied during the monitoring process; thus, inrushes were located within cross-section nonuniformly. The authors believe that the fact depends on the changes in component ratio of a stress field.

Mining and geological conditions to mine seam 385 with 1.33 - 1.8 m thickness at the distance of almost 950 m in Bogdanka mine (Poland) are close to those in Ukrainian Donbas mines. Studies, concerning rock deformations within boundary stations and deep ones, were carried out when 1/VI/385 (Herezy, 2015a) and 2/VI/385 (Herezy, 2015b) longwalls were mining.

According to the observation results in 2/VI/385 reused belt entry, it has been determined that rock stratification (even if it takes place out of the area affected by mining) was deeper than the deepest benchmark depth, i.e. 6 m. Rock deformation within the stratification zone were of alternating nature. Activation of rock shifts was observed at the distance of 100 – 150 m from the longwall being a boundary of mining affect. Benchmark shift at the depth of 6 m from the entry border was 0.08 m at the distance of almost 60 m from the longwall front. The fact means that radius of the rock failure area around the entry is much deeper than the indicated depth. In the context of the entry, rock deformations were 10 times more at the distance of 20 – 30 m to another longwall to compare with data concerning longwall one mining. Total rock stratification at the depth of rope bolt laying was 12% of the bolt length.

Boundary stations helped determine that maximum vertical deformation of the mine working boundary rocks was 2.01 m; minimum vertical deformation was 0.98 m; as for horizontal deformations, they were 0.65 and 0.25 m respectively. While approaching the longwall, both vertical and horizontal deformations become active at the distance of 100 – 150 m; they increased in accordance with power dependence. The author identifies three typical ones with 0.03, 0.125 and 0.55 mm/m shares at 1300 – 300, 300 – 100 and 100 – 0 m distances from the longwall front respectively.

Acoustic probe extensometric measurements in a mine working with 2 m length roof bolting performed under the conditions of coal mines in Teralba Colliery District (Australia) (Frith, Reed, & McKinnon, 2018) confirm that stratification of boundary rocks depend upon previous bolt tightening. If the previous loading is minor (i.e. 2 – 3 tons), then stratification takes place gradually from the mine working boundary to the depth of the rock mass. In this context, the shears increase in proportion to the depth. Deformation of boundary rocks is of decaying nature with shear velocity slowdown after 21 – 27 days the mine working was driven. After 51 days when the mine working was out of mining affect, deformation of its border was 0.117 m; it was 0.045 – 0.047 at 0.5 m depth from the border. 2.3 m depth limited the stratification zone. Increase in previous bolt tightening up to 8 – 9 tons factored into shear decrease within the boundary zone with 0 – 0.5 m depth. The shears decreased down to 0.04 m both within the border and at 0.5 m distance from it; stratification depth decreased down to 2 m.

Similar extensometric measurements were carried out in Moranbah North mine (Central Queensland, Australia) (Shen, 2013). 5.2×3.2 m square mine working was driven within a seam floor with 5.5 m thickness. The mine working was supported with the help of 2 m anchor bolts. Probes were pressed into wells drilled from parallel entry into the mine working roof before it was driven. Rock stratification was registered down to 4.5 m depth after a day of its construction. It has been determined that the anchored rock mass stratifies in a form of a single block; when a month past after the mine construction, rock fault at station 1 was 0.017; as for the station 2, rock fault was 0.051 m.

Hence, analysis of field observations, made in different world coal basins, confirm that deformation of a mine working border is of decaying nature. Active phase of deformations and stratifications within mine working takes place in a month after their construction. In this context, depth of the stratification zone, registered by mechanical benchmarks, is 2.0 – 2.3 m; it is almost 4 – 5 m according to the data by extensometers. Within the stage, deformation velocity was 4.0 – 4.5 mm/day. Increase in the dimensions of rock failure zone around a mine working slows down.

Within a zone of active effect of a stope, which borders are 30 to 100 m, depending upon mining and geological conditions, velocity of vertical boundary shifts is more than 4.0 – 5.5 mm/day; in turn, stratification depth and total boundary deformations are more than 6 and 0.8 m respectively. Failure zone increases actively. Shifts become active within the area of similar length (i.e. 30 to 100 m) in a zone of subsequent effect of a stope; however, absolute shift values are much greater to compare with those in front of the longwall one.

The study task involves:

– visual observations of the conditions of development mine workings within western longwall 11 of c_{18} seam;

– instrumental measurements of parameters of the mine workings within their typical areas;

– instrumental measurements of deformations of supporting components;

– visual observations and instrumental observations of roof rocks within terminal sites of the longwall.

2. RESEARCH METHODS

Instrumental observations in the context of development mine workings of MM "Pivdennodonbaske No. 1" were applied as the research methods. The measurements were carried out within typical sites of development mine workings of western longwall 11 (seam c_{18}) which were supported subsequently out of area affected by the longwall, within abutment pressure zone, in cross-section with the longwall, and behind it along with the longwall approaching.

The mine workings were selected on the basis of complicated conditions of seam mining, impossibility to provide baseline minimum horizontal section of ventilation raise for its reuse, and necessity to minimize expenses connected with construction of the mine workings and their support in the context of c_{18} seam.

Within mining site of western longwall 11 (seam c_{18}), coal seam is of simple and of complex structure consisting of two patches. Thickness of upper patch is 0.6 – 0.8 m; thickness of lower patch is 0.3 – 0.4; and thickness of intermediate rock is 0 to 1 m. The seam occurrence is undulating; seam inclination is 6 – 8°. Roof bond is satisfactory; floor bond is loose.

Slightly micaceous cross-bedding gray aleurite is the main of immediate roof. The aleurite is fissured. Frequency of the fissures and their strike coincide with the seam fracturing. In terms of lithological properties, it belongs to B_3 category. Thickness of the layer is 2.5 – 5.0 m. According to Protodiakonov, hardness coefficient is 3.

Quartzitic fine-grained gray sandstone is the main share of the main roof. Contact is sharp. In terms of lithological properties, it belongs to A_2 category. Sandstone with 0.7 m thickness and 3 – 4 hardness occurs within adjacent stratum at local sites; in a greater degree of the sites, aleurite prevails. Its upper layer share with up to 0.35 thicknesses is vulnerable to soaking. Floor has a tendency to its rise. It belongs to P_2 category; while soaking, it demonstrates P_2 – P_1characteristics.

Extraction pillar was mined to the dip by means of the combined system. The stope was equipped by powered system 1 MKD-90. Conveyor incline of western longwall 11 was driven behind the stope with construction between the mine working and mined-out area within a site where continuous chokes were observed. Conveyor incline of reused western longwall 12 was ventilation raise for the longwall; it was driven with the help of upper blasting and lower blasting. Packed line, made of cement-mineral mixture TEKHARD, was applied to protect observation areas.

KMP-A3 roof bolting with 11.2 m^2 finished section and 0.8 m spacing was used to support the mine workings. Within a zone, affected by mining, wooden props were set centrally under girders of each tie frame. Within ventilation raise, the props were set at 30 m length site in front of the longwall; they were set throughout the length of the belt roadway. Additionally, two anchors were set in the ventilation raise from girders of the basic support frames. According to recommendations by AURIRMMS, boundary measurement stations were engineered within the mine workings. 12 stations with 10 m spacing were prepared in belt roadway; in the ventilation raise, spacing was 8 m.

The observations took 40 days. 971 measurements were carried out. During the period, the stope advance was 30 m. Within the boundary stations, measurements were performed by means of flexible ruler (with 0.5 mm measuring accuracy). The measurements were performed twice a week. Moreover, photographic recording of ge-neral view of the mine workings within cross-section, supporting elements, and natural outcroppings was applied within areas of typical deformations in the mine workings and at finite areas of the longwalls. Furthermore, distances between fissures were measured as well as their crack openings, depths, and orientation towards the stope line. Besides, certain frames were drafted.

3. RESULTS AND DISCUSSION

Instrumental observations in the ventilation raise have demonstrated that within mine workings, supported in front of the longwall, period of intensive shifts correlated with the period when the mine working gets to abutment pressure area. That coincides with common idea of deformation processes within mine workings being supported in a zone of longwall affect (Ma et al., 2018a; Ma et al., 2018b; Nehrii, Nehrii, & Piskurska, 2018). It is possible to determine general characteristic of the mine working deformation while analyzing its height variations depending upon distance to the longwall (Fig. 1a). Convergence intensification is observed at 80 – 60 m distance to the longwall; vertical convergence is more than 1 m. Drafts of the mine working cross-section show general deformation dynamics (Fig. 1b).

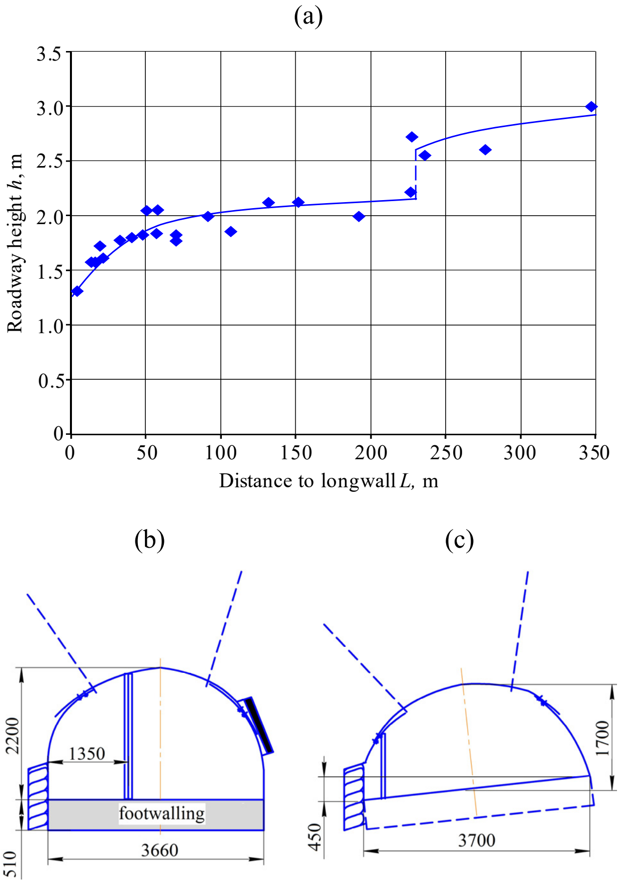


***Figure 1.** Graph of belt roadway height (h) of western longwall 12 (c_{18}) dependence upon distance to longwall L (a); drafts of the mine working cross-section at the distance of 229 (b) and 20 (c) meters*

Processing of the results of the measurements, concerning shears of the mine working boundary on benchmarks, helped obtain graphs of changes in total vertical shifts according to stations (Fig. 2a) as well as deformations of the floor rocks (Fig. 2b) within 65 – 6 m area in front of the longwall. Figure 3 demonstrates summary measurement results in the form of graphs illustrating dynamics of floor and roof shifts in a belt roadway of western longwall 12 (in terms of the Figure 3, measurement at 65 m to the longwall is taken as the defined zero).

Results of the instrumental and visual observations, performed in a belt roadway of western longwall 12, made it possible to determine the following:

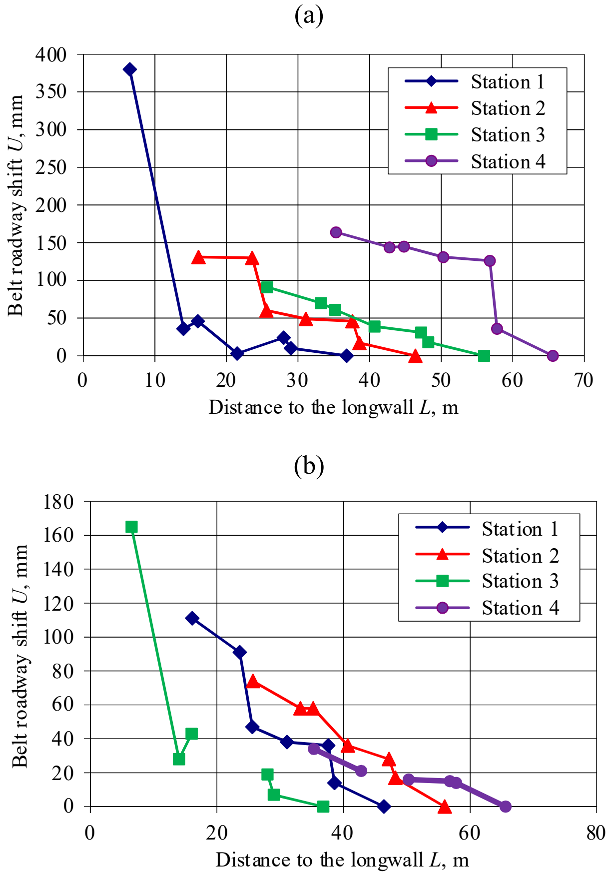
– during the whole operation period of the mine working, convergence of its floor and roof rock is 1.2 m on average;

– a value of a footwalling is up to 76% of total convergence;

– a velocity of the footwalling in the mine working within 6 – 65 m area in front of longwall was 3 mm/day on average;

– the floor rocks are represented as a discrete medium with small-section structure (Fig. 4).

Analysis of drafts, concerning the mine working state, has helped determine that changes in its boundary have characteristics of comprehensive asymmetric pressure. Much lighter stage of boundary deformation and breakage of support elements is observed from the mined-out area of previously extracted longwall.



***Figures 2.** Graphs of belt roadway shift U (western longwall 12, seam c_{18}) depending upon distance to the longwall L: a – total vertical convergence; b – footwalling*

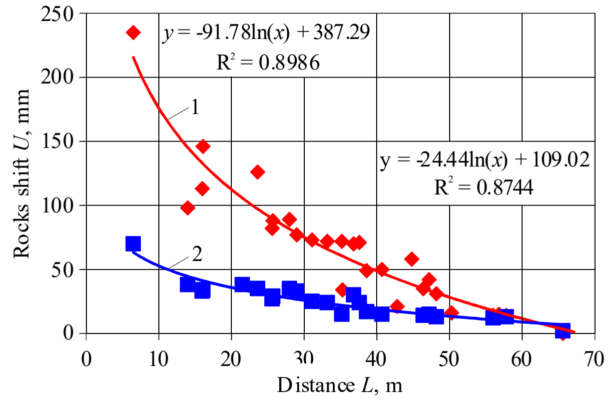


***Figure 3.** Summary graphs of floor rocks shift (a) and roof rocks shift (b) of a belt roadway in a western longwall (seam c_{18}) at the distance of 6 – 65 m in front of the longwall*

From the side, deformations of support legs and their pushing-out into a cavity of a mine working are local phenomena. From the side of coal rock mass, pushing-out of frame support legs is observed; the process depends upon rock crushing, and its shifting to a cavity of a mine working which results from the progress of a zone of broken rocks, their expansion, and abutment pressure action. From the side of a roof, subsidence and deformation of arching roof beams are seen; they result from shifts of rocks which vectors are perpendicular to a plane of rock stratification, i.e. left vertical 7 – 80 mine working deviation takes place.

Figure 4. General view of floor rocks shear of a belt roadway of western longwall 12 of seam c_{18}

Anchoring influenced roof shifts positively since it reduced them; however, the anchoring had kinematic connection with frames, and had harder mode than the frames. Thus, they produced deformations and breakage of the frame support elements. Taken as a whole, nonuniformity of rock shifts within the mine working boundary resulted in substantial deformation of the frames. In this context, fasteners from one side and another one were the basic nodes within which the processes took place (i.e. exhausted flexibility, sliding of fasteners along support legs, breakage of clamps and connectors, disconnection of roof beam and a leg in the point of their overlapping). Footwalling towards vertical axis of a mine working was asymmetric; prevailing pressing-out was observed closer to the lag, mounted from the side of the rock mass. Hence, inclination angle of the floor plane towards horizontal plane was almost 8º. Moreover, pressing of wooden reinforcement props into the mine working floor as well as protective packed line into rock, occurring under it, was also observed.

The major shifts in a belt roadway of western longwall 12 of seam c_{18} took place after the first longwall passage; pressing of support legs from the side of the mined-out area as well as deepening of protective structures into floor rocks confirm that. The abovementioned data result from the fact that floor rocks are represented by soft aleurite having raising tendency; moreover, it soaks if moisture is available. Hence, packed lines with limited flexibility were ineffective under the conditions and worked as dies.

During the observations, a belt roadway of western longwall 11 did not experience significant changes. The mine working is in satisfactory condition. No apparent deviations of cross-section from the design parameters are registered. During the observations, maximum shifts were 0.26 m at the distance of 15 m from the stope. A zone behind the mine working, affected by abutment pressure, extends to 50 m where intensive shifts of the mine working boundary rocks were observed. In this context, floor shifts were registered at the distance of 20 – 50 m; they were registered at 5 – 30 m distance if it was roof. Their stabilization and decay took place at the distance of more than 50 m from the longwall. The obtained results are similar to the results in (Solodyankin, Mashurka, Dudka, & Kuziaieva, 2015) confirming their reliability and correctness of the accepted research methods.

Analysis of deformation processes within terminal sites of the longwall, adjoining development mine workings, is also important since stability of natural outcrop as well as operational safety within the sites depends upon support parameters and mine working protection. Terminal sites and their communications with mine workings, driven behind longwall, are of critical importance. It is stipulated by the fact that under such conditions, support pattern involves cutout mining, timbering of vast areas using individual supports, construction of protective means as well as construction of a development mine working and its supports. That is, a number of operations to provide stability of wall rocks within the sites are performed in limited space; the operations are performed slowly involving a great share of muscular work. The conditions coincide completely with the conditions of conveyor incline of western longwall 11 and terminal site adjoining it.

Observations of roof rocks shifts within a terminal site have shown that their subsidence at the level of the last support of a face area was 21%. Its maximum value was 32% which was observed at the distance of 15 m from the seam edge along the mine working when flexibility of protective means and floor rocks is exhausted, i.e. at the distance of 7.5 m from its erection area. Thus, flexibility of continuous chokes and rocks under them was 41%. Significant flexibility was negative for the conditions of roof rocks and floor rocks within terminal site of the longwall.

Comparison of measurements of floor rock shifts within the mine workings, and roof rock shift along protective structure made it possible to conclude the following: intensification of floor rock pressing-out of a conveyor incline of western longwall 11 started from the moment when flexibility of continuous chokes and rocks under them is exhausted as well as when protective means start operating as a die. Observations of immediate roof within terminal site helped determine boundaries of potential caving.

Boundaries of the caving zone were determined according to artificial roof fracturing resulting from mining processes. The parameters differed in face area width. Tight fractures were registered at the distance of 2 m from the seam edge. One and two fractured zones could be identified within the zone. One of the systems was at the distance of 0.8 m from the edge and fissures, parallel to the face length, prevailed. Sometimes, their angle to the longwall length was 45º. Distance of the two other systems was 0.8 – 2.0 m from the seam edge. Moreover, fissures form different systems cut each other at the angle being close to straight one (Fig. 5). Locally, three fracture systems were observed; however, they were of a random nature and not pronounced. Nevertheless, at the distance of less than 2 m from the seam, within the site of prop stay 3, fracture opening and intensive roof rock deformation were observed. The process was followed by relative shift of rock blocks, and rock inrushes between roof beams.

Figure 5. Photos of natural roof outcrops at the distance of 0.8 – 2.0 meters from the seam edge including fracture systems orientation as for the stope length

Visual and instrumental observation of roof rocks condition within the terminal site of western longwall 11 of seam c_{18} (Fig. 6) have helped determine that the most dangerous inrush rock area is between 3rd and 9th prop stays of the face space, i.e. at the distance of more than 2.4 m from the seam edge.

Height measurements of the face space on the individual supports stays made it possible to obtain dependences of total convergence of roof rocks and floor rocks, and floor rocks shift separately upon the distance from the seam edge (Fig. 7). Taking into the fact that critical shits of the roof rocks U_c are 0.09 m (Nehrii, Sakhno, Nehrii, & Kolomiiets, 2017), the closest boundary of a zone of their caving is at l'_o = 2.7 m distance from the edge (Fig. 7). That rock caving zone coincides with the face space area where the main operations are performed. Thus, it is the place where caving should be prevented. Moreover, it is possible to reduce the likelihood of staff injury if cavity boundary zone is transferred beyond face space area, i.e. to protective means. Then, taking into account the fact that flexibility of protective construction as well as support parameters of terminal site effects its roof rock shift value (Frith, Reed, & McKinnon, 2018), it is possible to transfer cavity area boundary from the seam beyond the face space at the expense of reduced flexibility of protective means and prevention from its forcing into floor rocks.

Roof-bolting principle, which should meet the above requirements, is as follows: anchors in a borehole have to be fastened at the expense of their pressing throughout the length by means of mixtures, expanding while hardening, rather than at the expense of adhesion. First of all, calcium oxide-based unexplosive destructive mixtures (UDM) are promising.

(a)

(b)

Figure 6. Photos of natural roof outcrops when distance from the seam edge is more than 2 m (photographing direction is from the seam to protective structure; numbers indicate stays across the width of the face area of terminal site)

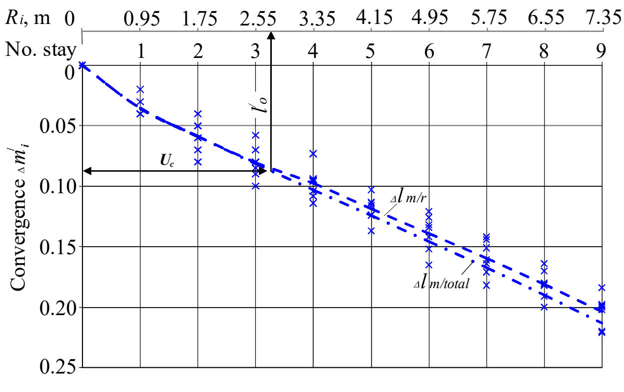


Figure 7. Graphs of total convergence Δ m/total, and roof shifts Δ m/r across the width of the face space to determine roof rock cavity boundary

During a process of hydration hardening, they can increase threefold when free; under the conditions of constrained deformations, arising within a borehole with anchor, they can develop up to 30 – 50 MPa pressure extension. Characteristics of such mixtures are studied rather thoroughly (Herezy, 2015b).

Use of the mixtures to fasten anchors results in the following: the expanding substance presses them between borehole walls regardless of their quality, and availability of dust and moisture. The mixture expanding factors into the changes in stress field around the anchored borehole; among other things, radial directions are available. That increases corresponding components of the stress field restricting progress and formation of fissures and any line defects within the rock mass as well as closure of fissures, oriented normally to vectors of radial stresses, favouring increased stability of a mine working.

In the context of the described concept, fastening self-expanding mixtures are innovative component. Specific requirements are applied to them. Such a mixture should develop 30 – 40 MPa expanding pressure under the conditions of constraint deformation; its share strength should be similar to the strength of coal formations; it should not be broken up within a borehole by changes in geomechanical stresses being typical for roofs of mine workings; and initial pressure of the mixture should be developed as quick as possible. Laboratory conditions were used to develop and study the modified mixtures.

4. CONCLUSIONS

Study of kinetics concerning deformations of boundary rocks in the development mine workings of western longwall 11 of seam c_{18} has made it possible to formulate following conclusions:

– within reused mine working, length of abutment pressure affect in front of longwall achieved 80 m where shifts of roof and floor rocks were 1.2 m on the average (share of floor rock shift was 76%); as for the mine working, driven behind the longwall, length of abutment pressure affect was 50 m and maximum convergence was 0.26 m;

– changes in the boundary of a mine working, supported behind the longwall, result from comprehensive rock pressure; its distribution was not uniform as for vertical axis of the mine working; thus, deformation of support elements and footwalling from rock mass prevailed;

– under the conditions of soft underlying floor rocks, pressing of protective means is observed. The process is followed by shifts of roof rocks; the shifts achieve up to 41% of the mined seam thickness;

– exhaust of flexibility of protective means and rocks, underlying them, factors into intensified pressing of adjoining mine working floor rocks;

– parameters of roof rock caving within terminal sites of longwalls have been determined; the parameters depend upon the parameters of the mine working and terminal sites timbering and protection.

The obtained results may be used to develop techniques and means which will provide stability of development mine workings and prevent from rock caving within terminal longwall sites. To do that, it is necessary to take into consideration uniformity of rock pressure distribution around the mine working within the zones affected by mining, and give special priority to the measures which will help provide stability of floor rocks of the mine working as well as those underlying protective means.

ACKNOWLEDGEMENTS

The study was a part of "Analysis of rock shift kinetics within development mine workings to work out measures aimed at their safe operation" research (State registration 0117U004317).

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ДОСЛІДЖЕННЯ КІНЕТИКИ ДЕФОРМУВАННЯ ПРИКОНТУРНИХ ПОРІД ГІРНИЧИХ ВИРОБОК

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Мета. Аналіз характеру деформування гірських порід та експериментальна оцінка стану гірничих виробок, що підтримуються в зоні впливу очисних робіт із виймання вугілля.

Методика. Дослідження проведено методом натурних інструментальних спостережень на вимірних станціях, обладнаних контурними реперами. Проведені виміри висоти і ширини виробки експрес-методом, в характерних ділянках підтримання накреслено ескізи та зроблено світлини. Дослідження проведено в конвеєрній і вентиляційній виробках 11-ої західної лави пласта c_{18} ДП "Шахтоуправління "Південнодонбаське №1" та їх сполученнях з лавою.

Результати. Встановлено, що зона впливу лави у виробці, що підтримується, повторно становить 80 – 60 м перед вибоєм, вертикальна конвергенція в цій зоні більше 1 м, доля підняття підошви близько 76%, швидкість зсувів більше 3 мм/добу. Виявлено, що в зоні впливу лави спостерігається локальне руйнування анкерної фурнітури та близько 70% деформування елементів рамного кріплення. На кінцевій ділянці лави з боку конвеєрної виробки встановлено, що ймовірна область вивалів порід знаходиться між 3-ою та 9-ою стійками привибійного кріплення, тобто на відстані від кромки пласта більше, ніж 2.4 м. Доведено, що застосування жорстких охоронних споруд в умовах слабких порід підошви без додаткових заходів неефективне, оскільки охоронні конструкції працюють як штампи. Стан конвеєрної виробки, що проводиться та підтримується за лавою, задовільний, деформації контуру знаходяться в межах піддатливості кріплення.

Наукова новизна. Встановлені закономірності деформування контуру гірничих виробок в умовах нестійких бічних порід пласта c_{18} ДП "Шахтоуправління "Південнодонбаське №1", що проводяться та підтримуються позаду очисного вибою та в подальшому використовується повторно для наступної лави. Встановлені закономірності видавлювання порід у порожнину виробки з-під охоронних конструкцій, що споруджуються уздовж виробки на межі з виробленим простором та закономірності вертикальної конвергенції порід на кінцевих ділянках лави.

Практичне значення. Використання результатів дослідження є основою для розробки способів та засобів забезпечення стійкості підготовчих виробок в умовах нестійких бічних порід, а також засобів запобігання їх обваленням на кінцевих ділянках лав.

Ключові слова: *стійкість виробок, гірський масив, деформації, кріплення, конвергенція*

ИССЛЕДОВАНИЕ КИНЕТИКИ ДЕФОРМИРОВАНИЯ ПРИКОНТУРНЫХ ПОРОД ГОРНЫХ ВЫРАБОТОК

С. Негрей, С. Сахно, И. Сахно, Т. Негрей

Цель. Анализ характера деформирования горных пород и экспериментальная оценка состояния горных выработок, поддерживаемых в зоне влияния очистных работ по выемке угля.

Методика. Исследование проведено методом натурных инструментальных наблюдений на измерительных станциях, оборудованных контурными реперами. Проведены измерения высоты и ширины выработки экспресс-методом, в характерных участках поддержания начерчены эскизы и сделаны фотографии. Исследование проведено в конвейерной и вентиляционной выработках 11 западной лавы пласта c_{18} ГП "Шахтоуправление "Южнодонбасское №1" и их сопряжениях с лавой.

Результаты. Установлено, что зона влияния лавы в выработке, поддерживаемой повторно, составляет 80 – 60 м перед забоем, вертикальная конвергенция в этой зоне более 1 м, доля поднятия подошвы около 76%, скорость смещений более 3 мм/сутки. Выявлено, что в зоне влияния лавы наблюдается локальное разрушение анкерной фурнитуры и около 70% деформации элементов рамного крепления. На конечном участке лавы со стороны конвейерной выработки установлено, что вероятная область вывалов пород находится между 3-й и 9-й стойками призабойной крепи, то есть на расстоянии от кромки пласта больше, чем 2.4 м. Доказано, что применение жестких охранных сооружений в условиях слабых пород почвы без дополнительных мер неэффективно, поскольку охранные конструкции работают как штампы. Состояние конвейерной выработки, проводимой и поддерживаемой за лавой, удовлетворительное, деформации контура находятся в пределах податливости крепи.

Научная новизна. Установлены закономерности деформирования контура горных выработок в условиях неустойчивых боковых пород пласта c_{18} ГП “Шахтоуправление “Южнодонбасское №1”, проводимых и поддерживаемых позади очистного забоя и в повторно используемых для последующей лавы. Установлены закономерности выдавливания пород в полость выработки из-под охранных конструкций, сооружаемых вдоль выработки на границе с выработанным пространством и закономерности вертикальной конвергенции пород на концевых участках лавы.

Практическое значение. Использование результатов исследования является основой для разработки способов и средств обеспечения устойчивости подготовительных выработок в условиях неустойчивых боковых пород, а также средств предотвращения их обрушения на концевых участках лав.

Ключевые слова: *устойчивость выработок, горный массив, деформации, крепления, конвергенция*

ARTICLE INFO

Received: 11 May 2018
Accepted: 6 December 2018
Available online: 20 December 2018

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