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Regularities of deformation of preparatory workings for reuse in weak rocks of the Western Donbas

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Abstract. Due to the influence of moistening and rheological processes, deformation characteristics of rocks decrease. This causes an increase in the actual displacements in the reuse workings compared to the calculated ones, which is not taken into account in the calculations, but is relevant for the mines of Western Donbas. Therefore, the purpose of this work is to conduct field measurements to determine the main regularities of deformation of the roof and soil of the workings in the zone of influence of cleaning works. The method of calculation of displacements for the conditions of mines of Western Donbas assumes constant and uniform in time (except for the initial period of 20...40 days after the excavation) growth of displacements of the rock contour of the excavation even outside the zone of influence of cleaning works. The monitoring data presented in this paper indicate the unsatisfactory condition of the workings that are reused. This indicates the imperfection of the calculation methodology. The study presents the results of surveying instrumental measurements and monitoring of the condition of preparatory workings during their reuse. The regularities of deformation of excavations under the influence of cleaning works in the conditions of Western Donbas are established.

1. Introduction

The technology of saving preparation workings for reuse most fully corresponds to modern requirements of economically efficient and safe underground coal mining. Failure to reuse mine preparation workings leads to a 2-fold increase in the length and cost of workings required to prepare the mine field. Therefore, the aimless technology of coal seam mining, which provides for supporting mine workings behind the longwall in order to reuse them, is an actual mining engineering problem.

There are a number of methods that allow to calculate the displacements of the roof of workings, including for the conditions of mines in Western Donbas [1-8]. But the results of these calculations do not reflect the real state of the mine workings after longwall mining. The calculations do not take into account many factors, the main of which are hydration of rocks and their rheological properties.

The unsatisfactory condition of preparatory workings is a problem that hinders the development of production. Deterioration of conditions for conducting and maintaining preparatory workings is caused by the increase in the depth of coal seams mining and intensity of their mining, which leads to an increase in mining pressure and stresses of the massif [9, 10]. The existing ways and means of ensuring the stability of workings in the zone of influence of cleaning works in many cases are insufficient. Scientific publications consider various methods of mine workings support: arch support [11-13], use of steel and rope anchors [14-17], frame anchoring [18-21], shotcrete [22, 23], preloading [24] or use of hydraulic



systems [25]. At the same time, the issues of supporting of workings in the zone of increased mining pressure from mining operations on neighboring seams and additional influence of dynamic pressure from the moving longwall face in weak water-saturated rocks are poorly studied.

Normative documents take into account the shape and area of the workings, the mining system, and the method of rock pressure control when calculating the load on the support [1-4]. In the studies [26-28] the joint analysis of the ground surface subsidence in the area of mining operations and in the boreholes ahead of the moving longwall is performed. The obtained regularities are used to predict the deformations of the protected objects on the Earth's surface and in the subsurface [29-30]. Thus, the load on the workings support depends on a number of factors, without taking into account which the correct determination of this value is impossible.

It is assumed that the movement of the rock contour of mine workings has a constant and uniform character in time. However, deformation and change of contours of real mine workings refute this statement.

The purpose of the performed research is to carry out field measurements to determine the basic regularities of the behavior of the roof, soil and sides of mining workings in the zone of influence of cleaning works. Further use of the results of field experiments will make it possible to take timely measures to strengthen the necessary section of preparatory workings, which are used repeatedly, in conditions of weak host rocks. Experimental studies were conducted at two mines in Western Donbas.

2. Research object characteristics

At the PSD Stepova mine, PJSC DTEK Pavlohraduhillia (Ukraine) the preparatory workings of longwall faces No. 157 and No. 161 have been passed. 157th and 161st ventilation drifts are extinguished after the cleaning face, 159th and 163rd conveyor drifts are maintained for gas-air mixture removal to the drainage drift.

At the PSD Heroyiv Kosmosu mine, PJSC DTEK Pavlohraduhillia (Ukraine), when working longwall face No. 1061-bis (figure 1) there was a problem with protection of 1061-bis conveyor and 1061-bis ventilation drifts ahead of the moving longwall face.

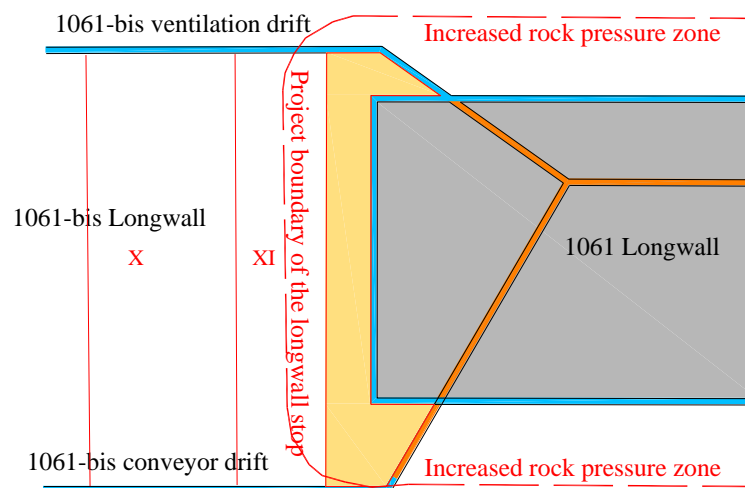


Figure 1. Extract from the plan of mine workings on the seam c_{10} .

Preparatory workings of longwall faces No. 157, 161 and 1061-bis are located in identical mining and geological conditions, which expands the opportunities to study the general regularities of deformation of the workings sections in the longwall influence zone.

The panel length is 900–1200 m, longwall face length is 250 m, average mining depth is 350–420 m, seam dip angle is 3° . The coal seam is predominantly of simple structure, the geological thickness averages 0.9 –1.05 meters. The coal seam is hazardous in terms of gas and dust. Is not prone to spontaneous combustion.

Special observation stations were set up in the zone of influence of longwall faces No. 157 and 161 to study deformation of sections of supported preparatory workings.

3. Methods

3.1. Instrumental observations in the 159th conveyor drift

In the 159th conveyor drift there were 5 measuring observation stations located at PK142, PK144, PK146, PK148 and PK150 pickets. At each station a number of measurements was made to assess the geometric parameters of the section, their change over the time interval between observations and deformations of the contour rocks. The scheme of measurements at the observation station is shown in figure 2.

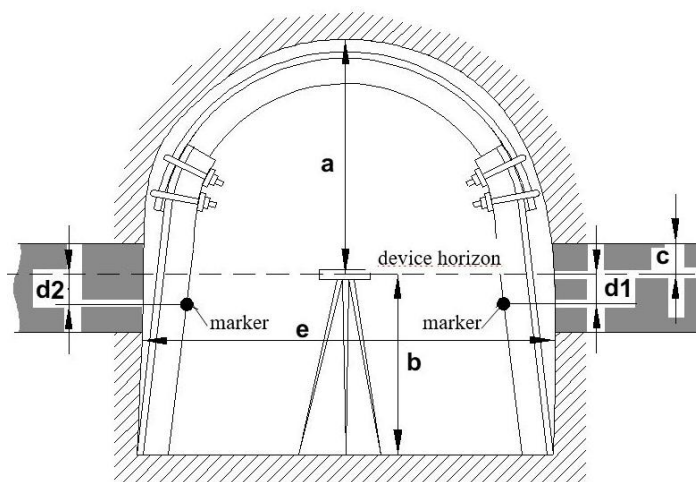


Figure 2. Scheme of surveying measurements at the observation station. Distance from the device horizon (DH): a - to the roof of the workings; b - to the ground of the workings; c - to the roof of the formation; d1, d2 - to the marks on the support legs; e - width of the workings at the DH level.

A total of 10 series of instrumental observations were made at the observation stations of the 159th conveyor drift at different positions of the face at the observation dates relative to the observation stations.

The measured data were used to calculate the values of lowering (rising) of the soil and the roof of the workings relative to the formation roof and the total vertical convergence and to plot the sinking (rising) of the soil and the roof of the workings relative to the formation roof and the total vertical convergence (figure 3).

All graphs have a common moment in time: the longwall crossing of the section where the observation station is located (the value of the distance from the face to the observation station equal to 0).

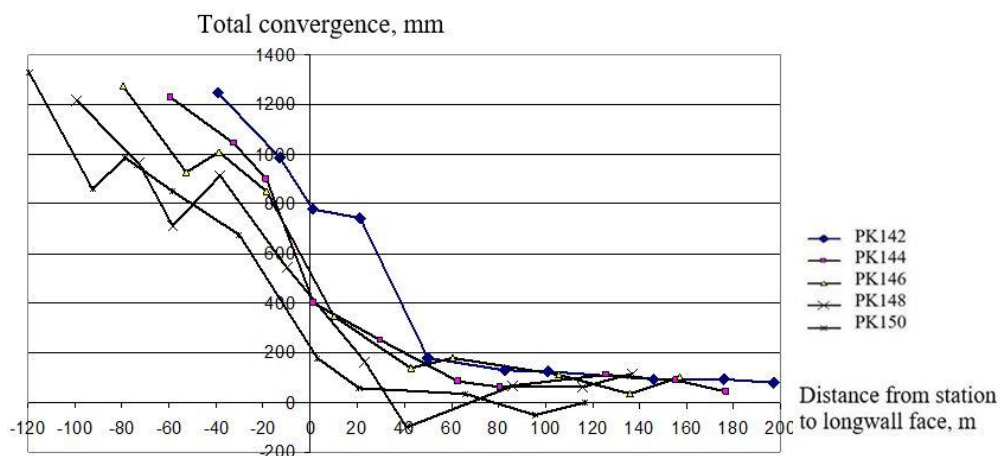


Figure 3. Summary graph of the overall convergence of the 159th conveyor drift.

3.2. Observations in the 163rd conveyor drift

In the 163rd conveyor drift there are 5 measuring observation stations located at PK192, PK194, PK196, PK198, PK200 pickets. The scheme of measurements at the observation station is shown in figure 3. The first observation at the stations was made at the position of the longwall face No. 163 at a distance of 140 m from PK200 picket. At the observation stations of the 163rd conveyor drift 10 series of instrumental observations were made.

The summary graphs for the 159th and 163rd conveyor drifts have a common character of the distribution of workings deformations and their commensurate values. The similarity of mining and geological and mining engineering conditions of the longwall face No. 157 and 161 gives grounds for joint analysis of the results of in-situ measurements at the observation stations of the 159th and 163rd conveyor drifts (figures 4-6).

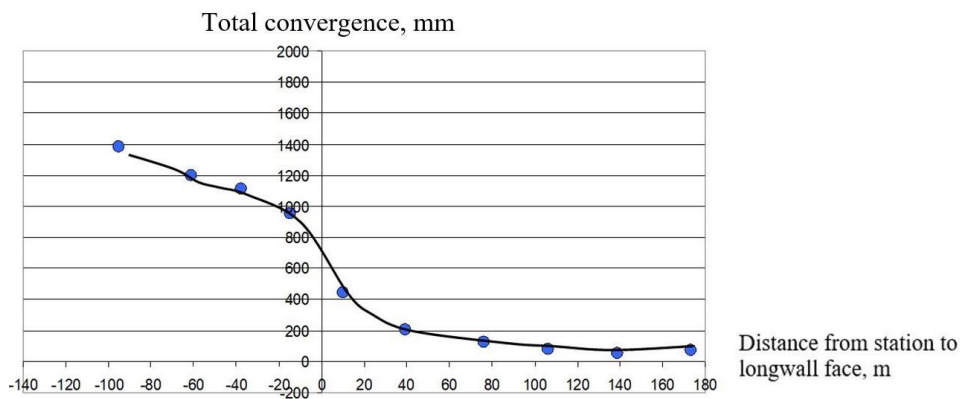


Figure 4. Smoothed convergence graph of 159th and 163rd conveyor drifts.

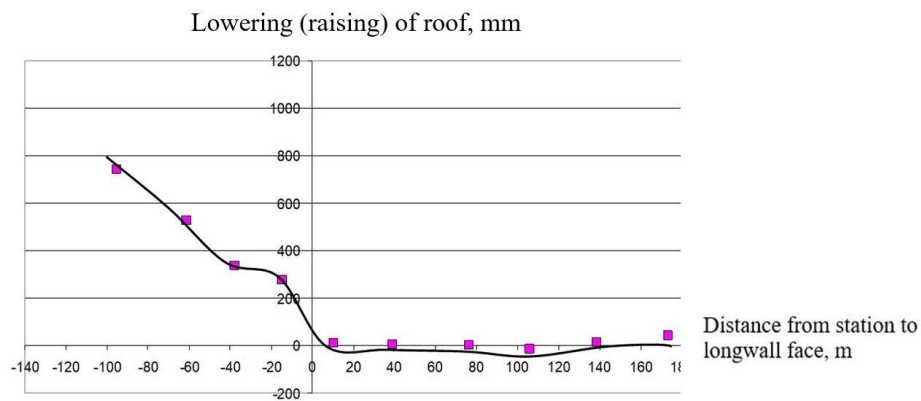


Figure 5. Smoothed graph of roof lowering of the 159th and 163rd conveyor drifts.

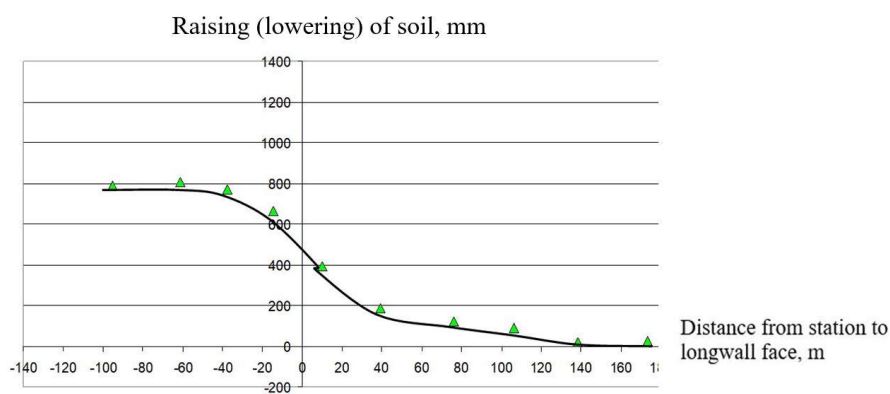


Figure 6. Smoothed graph of soil raising of the 159th and 163rd conveyor drifts.

3.3. Observations in 1061st-bis ventilation drift and 1061st-bis conveyor drift

Monitoring of the excavation condition included visual observations of the support behavior, as well as periodic measurements of the contour observation stations installed in the 1061st-bis ventilation drift (PK10 and PK15) and in the 1061st-bis conveyor drift (PK10). The contour station (figure 7) is a wooden stake driven into the rock in the roof and sides of the working face.

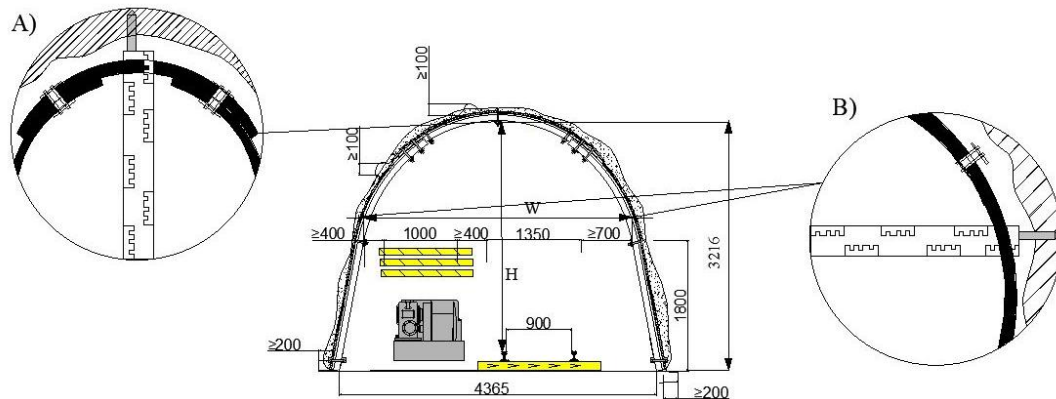


Figure 7. Supporting of preparatory workings of longwall face No. 1061-bis and the scheme of measurements; A – measurement of vertical convergence; B – measurement of horizontal convergence.

During the measurements of the workings cross-section the total vertical convergence (H) and horizontal convergence of the face (W) were determined depending on the longwall face position.

4. Results and discussion

Systematized and generalized results of observations at contour stations on vertical and horizontal convergence are presented in figure 8.

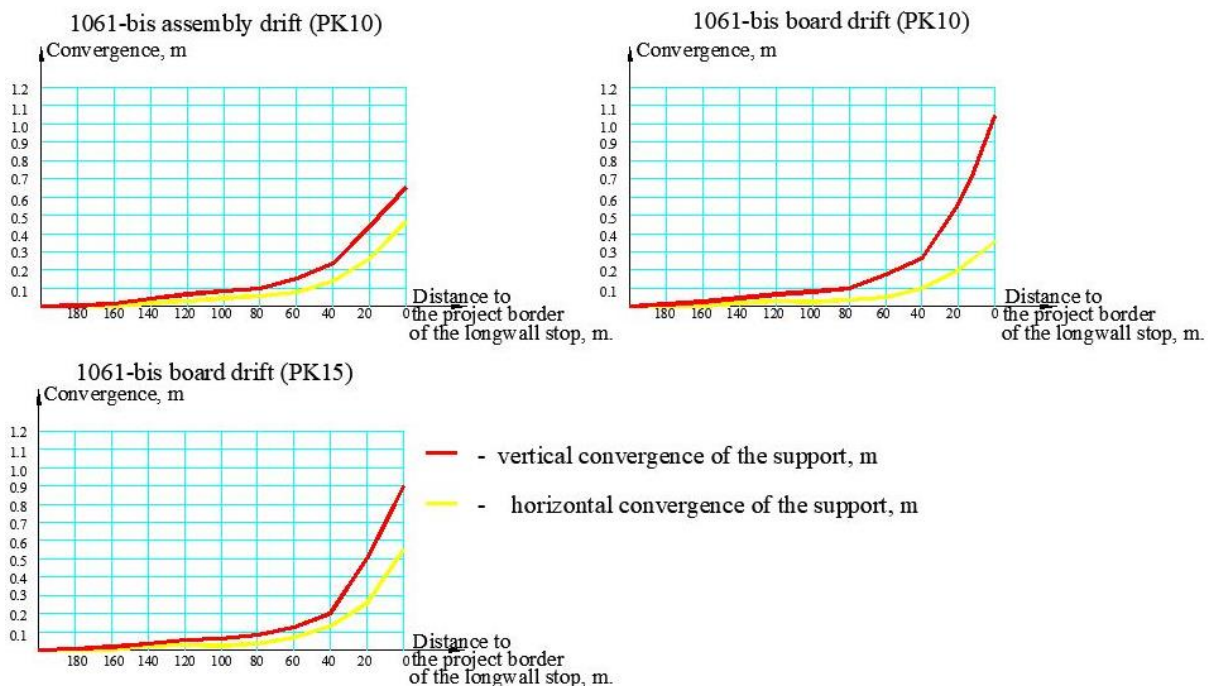


Figure 8. Graphs of vertical and horizontal support deformations as a function of the distance to the longwall face.

The results of the convergence observation indicate the following regularities: when the longwall face is approaching at a distance of 20 m up to the project border of the longwall stop, the support is not significantly deformed and the convergence does not exceed the background one for these mining and geological conditions. As the longwall face advances, the preparatory workings are significantly deformed due to the increase in horizontal stresses of the massif. This leads to deformation of one of the faces on the face side (figure 9).

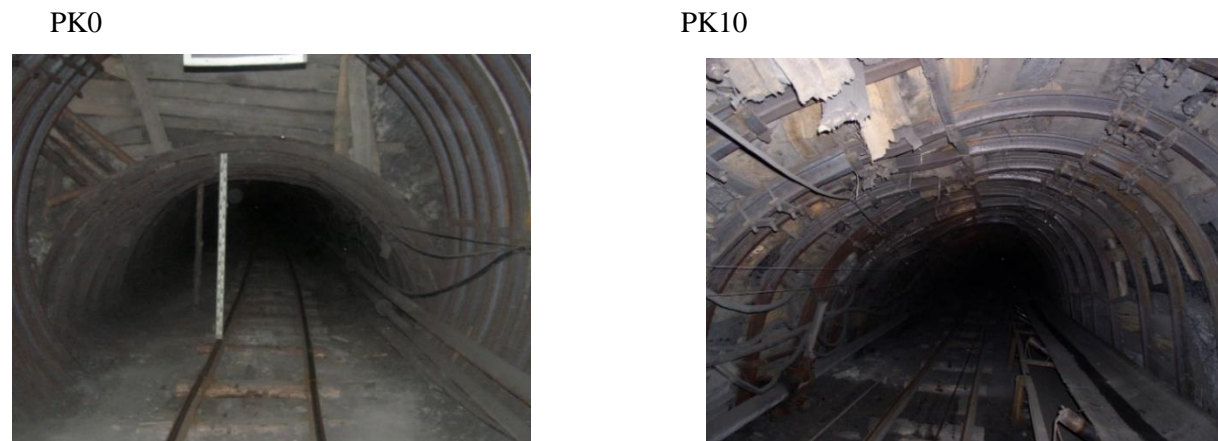


Figure 9. Condition monitoring of the 1061st-bis ventilation drift.

Observations of vertical convergence after longwall stoping (figure 10) allowed us to establish that in the first 10-18 days, the pressure on the support of the preparatory workings and, consequently, its deformation is maximum. Attenuation is observed from 25-30 days of the stoping. Preparatory workings on the 30th day lost about 60% of their original cross-section. The deformed sections of the workings started to be re-bonded on the 45th day after the stoping of the 1061st-bis longwall face.

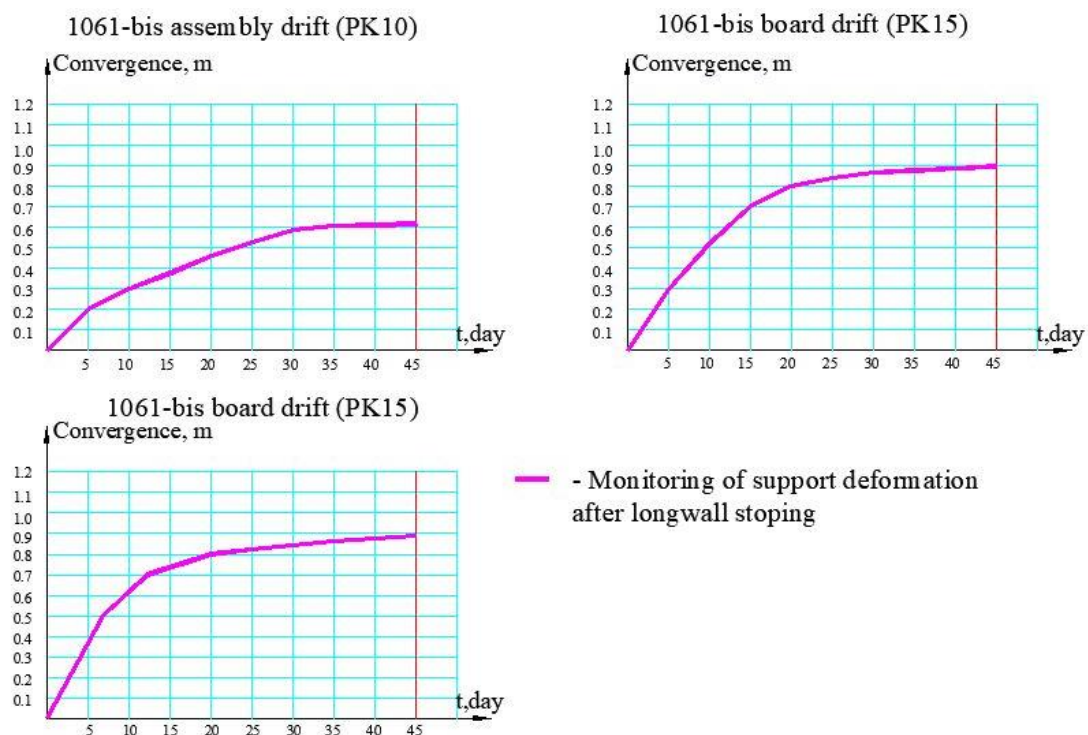


Figure 10. Graphs of vertical and horizontal deformations of the support as a function of longwall stoping time.

5. Conclusions

The general analysis of the results of experimental observations at the mines Stepova and Heroyiv Kosmosu leads to the following conclusions about deformation of sections of preparatory workings supported in the zone of influence of mining workings:

- vertical convergence in the preparatory workings starts at a distance of 150 m from the longwall face and reaches maximum values of 2500-3000 mm when the face is removed to a distance of 200 m;
- in the section of the excavation coinciding with the line of the longwall face, the average convergence is 600-1000 mm or about 25-30% of the maximum;
- the development of convergence in time as the longwall face passes through the face follows a law described by the Gaussian integral function;
- the roof of the workings in relation to the roof of the coal seam remains stationary until the longwall face approaches at a distance of about 10 meters;
- starting from the distance to the longwall face of 10 m, there is an intensive lowering of the excavation roof, which obeys a linear law – every 10 m increase in the distance in the worked-out part from the excavation section to the longwall face results in a consecutive lowering of the roof by 100 mm;
- soil uplift in the preparatory workings starts at a distance of 150 m from the approaching longwall face;
- the development of soil uplift at the interval of 150 m before the longwall face and 150 m after the longwall face occurs according to the Gaussian integra;
- at the moment of the longwall face passage the soil uplift in the excavation cross-section reaches 600-800 m.

The established regularities of deformation development in the preparatory workings allow to predict the stability of workings supported in the worked-out part of the longwall faces in the conditions of mines in Western Donbas, to assess their suitability for venting of gas-air mixture and to carry out timely technical measures to support the workings.

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