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## Problems of land reclamation during liquidation of coalmining enterprises

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**Abstract**. The paper presents data on the influence of coal-mining industry elimination on the deformation of land surface which can cause accidents and destructions of buildings and constructions located nearby the closed pits or mines. The analysis is carried out and the major factors which influence change of the intense deformed condition of the massif of rocks were revealed. The example of the monitoring system which will provide researchers with information for preparation of the project of a pit or a mine closing is presented, and it also will allow one to predict behavior of the massif in the future.

#### **1. Introduction**

The analysis of the actual costs of coal-mining restructuring needs has shown that elimination of excavations in a total amount takes a small part (5.7%), and among other main expenses the highest expenses is the cost of consequences mitigation after mining operations have been done (27.8%) [1].

At the beginning this circumstance was explained by the absence of scientific and technical ensuring restructuring which has led to the fact that projects on closing mines and pits have not considered prevention of harmful effects from conducting mining operations after their stop. But the solution of environmental problems at liquidation of the coal enterprises has gained paramount value [1, 2]. At the same time, as a rule, the most of the closed enterprises are situated on the territories with a high degree of urbanization and are close to large settlements.

The analysis of such consequences shows that in the zones of the liquidated enterprises influence, complex environmental problems appear in connection with change of the hydrogeological conditions as a result of the returning of underground waters to the natural historical level which took place before mining [2, 5].

Closing coal mines and pits with their transfer to "wet" preservation or water management recultivation is followed by flooding of the developed space and restoration of underground waters levels.

At the same time there is a flooding and bogging of territories, pollution of water intakes and reservoirs, landslide processes become more active and the stress state of rock massif changes.

Development of landslide processes in borders of subsidence troughs near the flooded "Capitalnaya" mine (The Kuznetsk basin) has caused, due to displacement of covering deposits from 2 to 8 meters in depth, damage of houses in the town called Osinniki that demands at the moment resettlement of 3 thousand inhabitants [4]. The similar situation has developed also to Karpinsk [6].

Many of negative and dangerous processes at the liquidated enterprises do not prove themselves

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instantly but only months and years later. That is why the majority of such processes are difficult to predict.

Only in the period of 1998-2000, to solve these problems various organizations have performed more than 120 research works connected with ecological aspects of mines and pits elimination. On their basis, a number of the normative documents have been created. They are designed to regulate an order of technical works performance during the liquidation of the coal-mining enterprises and compliance with the ecological standards in a zone of their influence [2, 3].

The majority of researches were carried out for underground coal-mining which prevails among the closed enterprises. However, on the operating open-cast mining in general there are the same processes as on underground one. They are: the continuous deterioration in development conditions and increase in capital investments [4]. It allows one to expect further increase in quantity of the closed coal pits, but insufficiently detailed studying of negative aspects of such actions can lead to very dangerous ecological consequences.

At the same time in Russia a transition from an underground way of coal mining to more effective – open one is systematically carried out (fig. 1). During 1993-2003, the number of the operating coal mines was reduced from 231 down to 95, and the number of pits has increased from 65 up to 121 [8]. Now in the coal industry of Russia 241 coal-mining enterprises are operating and they are 104 mines and 137 pits [6]. In the general production, the share of the open way will increase up to 70-75% and, by some estimates, it will make 80-85% by 2020 [4, 7, 9]. There is an increase in a share of an open way of coal fields developing in some other countries too. For example, the share of open-pit coal-mining is: in Australia – 67%, in Canada – 90% (Kirukov V V 1997).



Figure 1. The changes of the open way share in the general coal mining in Russia [4].

The prospects of coal-mining branch development in our country are defined by "The energy strategy of Russia for the period till 2020" according to which coal mining in 2020 will increase up to 430 million tons.

So large coal reserves in bowels of Russia will be the main power raw materials and will have a strategic importance. This circumstance assumes that in the future an intensification of coal fields development in the country and the open way of production will prevail.

#### 2. Practical example

At the end of the last century, the main reserves of coal provided by the project on the pit "Youzhny" have been extracted. This pit is the main field for output of brown coals in Northern Urals. Mining operations were performed behind technical border (working off of off-balance stocks) with use of technology of filling the developed space. That is why the shareholders have made the decision on elimination of a pit "Youzhny" with the natural flooding of residual excavations during the accepted water management direction of recultivation.

The deposit is dated from the Mesozoic complex presented by thickness of the interstratifying soapstones, aleurolites, sandstones, conglomerates, clays and coals with a general thickness about 300

m. At the time of working off completion the pit was a ditch with the area of 15 sq.km and more than 200 m in depth with tilt angles of boards 15-20 degrees. The western non-working board was loaded with the internal dumps created under corners of a natural slope. The east working board characterized by a tilt angle 15-20 degrees and 180 m height. It was located near industrial and civil buildings of Karpinsk.

During coal mining on the boards of the pit, there were problems with stability which were solved by application of drainage by vertical wells. The elimination of the pit has led to the termination of drainage works and the rock massif which have been drained was flooded that has affected deterioration in boards stability conditions. That is why, on the east board of the pit the action against landslide have been executed with use of a load of the local slope (fig. 2) with an overburden rock mass (4.5 million m<sup>3</sup>).

A control of the boards stability have been doing by the means of a hydrogeomechanical processes monitoring, which includes surveying of the board deformations on 5 profile lines and change of underground waters pressures on 8 observation wells equipped with sensors of pore pressure at various depths of the studied rock mass of Mesozoic and Paleozoic age.



**Figure 2.** A schematic geological section of the east board of the pit "Youzhny" near the observation line No. 8: 1 - limestone; 2 - breccia clay; 3 - bauxitic clay; 4 - conglomerates; 5 - soapstone; 6 - sandstone; 7 - coal; 8 - dumps; 9 - explosive violations; 10 - observant reference point and their number; 11 - water levels in career in June 2003 (+108 m) and in the end of the flooding (+179 m); 12 - territories of bakery (I) and milk plant (II); 13 - the observation well 3vn with sensors of pore pressure.

The stationary regime observations have allowed one to record landslide deformations on local sites of the board and raising of the land surface in the territory adjacent to the pit where buildings and constructions of different function are located (Bakery, Milk plant, the power line, a collector, etc.).

The facts of the surface raising caused by the growth underground waters pressures due to flooding have appeared because of recently coal mines closing. The flooding of the pit of such scale in Russia is carried out for the first time. The results of the vertical shifts observations with the base stations put on east board of the pit "Youzhny" are given in fig. 3. Rise in water level in the pit during the executed observations has made 12 meters. The raising of the land surface between reference points No. 6 and No. 13 (fig. 3) is caused by the rock massif stress state change at increase in underground waters pressures drained earlier. It has predetermined a possibility of elastic deconsolidation of rocks and, as

a result, a raising of the land surface.

At the same time in the pit boards on sites of a limestone's exit to a day surface (or under quaternary deposits), the land surface raising is observed. Within terrigenous thickness both deformations are fixed: the raising one and the subsidence deformations caused by the shear plastic shifts determined by features of a rocks bedding growing on contacts on local sites of the pit board.

The problems of negative consequences of coal pit flooding can be considered in two aspects.

On the one hand, the changes of the hydrogeological conditions can cause decrease in degree of rocks stability at the boards of the pit and it can become the reason of deformations development at the boards, ledges and adjacent sites of the land surface within width of a possible sliding prism, creating a threat of various buildings and constructions safety.

On the other hand, the rise in water level and restoration of underground waters pressure in the adjacent territory can lead to deformation of the land surface in the territory of former drinage.

Therefore, the forecast of flooding consequences during water management recultivation comes down to the forecast of two gravitational geoengineering processes development: landslides of the boards and ledges and deformations of the land surface in adjacent territories.

In generaly, stability of the east board of the pit "Youzhny" is provided with stability margin coefficient not less than 1.3. At the same time it is possible the appearance of the local deformations on the certain sites of the board.

Calculation of the land surface deformations as a result of the section flooding has shown that because of underground water level rising in the pit, uneven positive shifts (raisings) on the land surface are possible, with the maximum vertical deformations up to 13 cm at a distance of about 230 m from the pit border.



**Figure 3**. Vertical deformations of reference points on the observation line No. 8 between 7 and 1 series (804 days).

#### **3.** Conclusions

Large coal reserves in bowels of Russia will be the main power raw materials. It is possible to assume that there will be an intensification of coal fields development. At the same time, transition from an underground way of coal mining to an open one is carried out systematically in Russia. In the general production, the share of the open way will increase up to 70-75% and, by some estimates, it will make 80-85% by 2020. It means that scales of impact from mining on the environment will increase; in

particular, the areas of the broken lands will increase rapidly.

The Russia's coal industry large-scale elimination of unprofitable and unpromising coal mines and pits has revealed some problems. During closing of the mining enterprises, besides an ecological situation improvement, there is also an activization and emergence of the new dangerous geological processes and the phenomena capable to affect geoengineering conditions of the former coal deposits' territories.

Relevance of land reclamation problems is caused by urgent need in ecological safety ensuring in territories of open mining operations even when they are ended. Also there is need in fastest and safe development of the broken lands which are situated, as a rule, in densely populated areas (regions).

The scientific and methodical principles of geoengineering ensuring during elimination of the mineral deposits excavations developed using the open cast mining are at an insufficient level today. It is necessary to perform special researches for studying geoengineering conditions to be able make a forecast of their change as a result of the remediation works. One of the tools which can provide sufficient information is a monitoring based on geological processes developing models.

The system of geoengineering ensuring during the open cast minings elimination has to include: studying and an assessment of geoengineering conditions, the forecast of these conditions changes under the influence of the reasonably chosen direction of recultivation and the local geodynamic monitoring of conditions' changes which has to be carried out throughout recultivation of the pits.

The general hydrogeomechanical model of an object (a pit, the site of a board, the adjacent territory, etc.) has to be a basis of the geoengineering estimates and forecasts received within organized system of geoengineering during liquidation of the open cast coal-minings. This system can be divided into several models depending on the arising and developing geological processes and phenomena.

The water management recultivation of the pits is followed by change of geoengineering conditions of the rock massifs and territories adjacent to excavations that affects the general geodynamic situation of the area, provoking development of dangerous geoengineering, such as landslides and raising of the land surface.

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