ENVIRONMENTAL ISSUES PREDICTION METHODS FOR ESTONIAN OIL SHALE MINES

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Abstract. The paper deals with the mining block stability prediction methods and the influence of the collapsed blocks on the environment in Estonian oil shale mines. It is proposed five prediction methods which enable to determine the negative impact on the environment. Methods are applicable for different geological conditions and will be very useful for environmental protection specialists.

Keywords: mining block, collapse, environment, pillar, underground excavation, stability prediction methods, subsidence.

1. Introduction

The mineral wealth of Estonia is located in a densely populated and rich farming district. It is known that the results of mining may suddenly appear on the environment many years later after the end of excavation. The post technological processes of the underground mining caused and will cause in the future a large number of technical, economical, ecological and juridical problems.

Processes in the mines, which appear during or immediately after their exploitation, are under the control of the miners. They have entire image of the results of the mining and the means for the control of these processes. At the end of the mining works the control of these processes stops and get sometimes even impossible. During long or short time the mining enterprise loses the responsibility of the results of its activity. Mining enterprise performs the investigations of the immediate influence of the mining works on the environment, but it is not interested in the estimation of the results of the post technological processes. Accordingly, the post technological processes are an extensive environmental problem.

The scientific purpose of the investigation is to elucidate the basic mechanism of these processes, elaborate the prognosis methods and give the uncertainty estimation of the results. The practical aim is to estimate the location, area and time of a collapse in a mining block and elaborate design methods for mining constructions.

The first spontaneous collapse of the pillars and the surface subsidence in an Estonian oil shale mine took place on 1964. Up to present, it have been recorded 73 collapses on the area of 100 km$^2$ [1]. Consequently, the post technological processes continue up to present.

The research is based on the hypothesis that the strength and elasticity parameters of the rock in the pillars and roof depend on time. Due to the rheological processes the pillars and overburden rocks may undergo destruction and consequently, the surface subsidence.

Elaborated calculation methods are applicable in different geological conditions and for prediction the life-time of the underground constructions. The surface subsidence parameters will be determined by conventional calculation schemes. Cooperation with different specialist, the calculation methods enable to predict and reduce the harmful impact on the environment. The applicability of these methods is clearly demonstrated.
2. Geology and mining

The commercially important oil shale bed is situated in the north-eastern part of Estonia. The oil shale bed lays in the form of a flat bed having a small inclination in southern direction. Its depth varies from 5 to 150 m. The commercial oil shale bed and immediate roof consist of oil shale and limestone seams. The main roof consists of carbonate rocks of various thicknesses. The characteristics of the certain oil shale and limestone seams are quite different.

In Estonian oil shale mines the room-and-pillar mining system is used. The field of an oil shale mine is divided into panels, which are subdivided into mining blocks, approximately 300-350 m in width and from 600-800 m in length each. A mining block usually consists of two semi-blocks. The oil shale bed is embedded at the depth of 40-70 m. The room is very stable when it is 6-10 m wide. The pillars in a mining block are arranged in a singular grid.

3. Prediction methods

The mining block stability calculation methods allow determine the location, area and time of the collapse.

3.1. Stability prediction by life-time of the pillars [2].

The method uses the conventional calculation scheme. For the calculations a special program was elaborated. The results are presented on the map of a mining block, where the life-time of each pillar is indicated and classified (Fig.1). Method allows determine the location and parameters of the collapse center in a mining block. Exactness of this method is not high and the results depend on the subjective factor. Method is relatively simple and it is suitable for preliminary calculations.

3.2. Stability prediction by statistical methods [3].

The standard programs are used for statistical analysis. Method bases on the normal distribution control of the cross-sectional area of the pillars. Investigation is based on the following assumption: by normal distribution of the pillars cross-sectional area a potential collapse of a mining block can be expected (Fig.2). Method does not determine the collapse parameters, but determines the collapse possibility/impossibility.

Figure 2. Normal distribution control of the pillars cross-sectional area for the Ahtme (A) and Estonia (B) mines
Figure 1. Stability prediction by life-time of the pillars. Mine Estonia, block No.705
1 – pillars with life time $t \leq 6$ months; 2 – pillars with life time $t > 12$ months;
3 – pillars with life time $6 < t \leq 12$ months; 4 – collapse area; 5 – collapse center.
3.3. Stability prediction by rate of current rock strength [4, 5].

The method is suitable for short-term calculations (up to 6 months) and bases on the rheological behavior of the rock (Fig.3).

![Figure 3. Rock weakening process with time [1]](image)

- observation data

For the collapse prediction the relative uncertainty in time exceeds 66% at the 95% confidence level. It is of no particular interest for practical purposes.

3.4. Stability prediction by roof-to-floor convergence

The method is suitable for long-term calculations (up to 100 years and more, uncertainty does not exceed 10%). Method bases on the roof-to-floor convergence, measured of in situ condition by means of bench mark stations in the mining block (Fig.4).

![Figure 4. Roof-to-floor convergence curve](image)

ε – deformation; t – time; \( \varepsilon_u \) – ultimate deformation at fracture; \( \varepsilon_e \) – elastic deformation; \( t_p \) – time at the fracture; \( \dot{\varepsilon} \) – deformation rate; I – elastic deformation, \( \varepsilon_e \); II – transient creep, \( \dot{\varepsilon}<0 \); III – steady-state creep, \( \dot{\varepsilon}=\text{const} \); IV – transient creep, \( \dot{\varepsilon}>0 \);
In the calculation the deformation failure criterion is used. If a mining block is abandoned, the access is closed. In shallow mines (depth less than 100-150 m) it is possible to perform the measurements on the surface, using the conventional or modern (GPS) equipments.

3.5. Stability prediction by conditional thickness and collapse time.
The method bases on the analysis of the conditional thickness contours on the map of a mining block, taking into consideration the influence of the different factors on the stability (superposition principle) (Fig.5).

![Figure 5. Conditional thickness contours of the Ahtme mine block No.60 (A) and Estonia mine block No.101 (B)](image-url)

A – area of the potential collapse; B – center of the potential collapse

Conditional thickness represent the height of a prism whose cross-section equals the pillar cross-sectional area [4]. Method is cheaper and simpler (uncertainty does not exceed 5%) than roof-to-floor convergence one. Elaboration of this method is cumbersome, time consuming and demands exact knowledge about the processes in the rock mass and constructions.

4. Conclusions and recommendations

The following conclusions and recommendations can be made on the results of this study:
1. The post technological processes of the underground mining caused and will cause in the future a large number of different problems. The mining block stability and surface subsidence is very actual problem in a densely populated and intensely farmed district, like NE Estonia.
2. The processes in the mines, which appear during or immediately after their exploitation, are under the control of the miners. Mining enterprise is not interested and not capable in the estimation of the results of the post technological processes.
3. Investigation showed that the prediction of the influence of the post technological processes on the environment is possible to perform by five methods. For long-term calculations suit the prediction methods by roof-to-floor convergence, and by conditional thickness and collapse time.

4. Estonian and worldwide experience have shown that the problem is actual and we have all the possibility and means for the prediction the collapse parameters by underground excavation. Methods are applicable for different geological conditions.

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Bibliography