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MINING BLOCK STABILITY ANALYSIS IN ESTONIAN OIL SHALE MINES BY STATISTICAL METHODS

IGAUNIJAS DEGSLĀNEKĻA BLOKU STABILITĀTES ANALĪZE AR STATISTIKAS METODĒM

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Abstract. *This paper analysis the stability of the mining blocks in Estonian oil shale mines, where the room–and–pillar mining system is used. The pillars are arranged in a singular grid. The processes in overburden rocks and pillars have caused the subsidence of the ground surface. Statistical analysis of the pillars cross–sectional area evaluated the calculations. Normal distribution control allows determing the stability of a mining block. By normal distribution of the pillars cross–section area a potential collapse of a mining block can be expected. Theoretical and in situ investigations in Estonian oil shale mines showed that their results are close to the modeling ones. The surface subsidence parameters will be determined by conventional calculation schemes. Presented method suits well for mining block stability analysis and spontaneous failure prognosis.*

1. Introduction

The most important mineral resource in Estonia is a specific kind of oil shale. Its deposit is located in a densely populated and intensely farmed district. It is estimated that about 80–90% of the total underground oil shale production is obtained by room–and–pillar method. The area mined by this method reaches 100 km^2. It has become apparent that the processes in overburden rocks and pillars have caused the mining block collapse accompanied by significant subsidence of the ground surface. The first spontaneous collapse of the pillars and surface subsidence took place on 1964. Up to present, 39 failures in Estonian oil shale

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mines have been registered, which make up 9% of the total number of mining blocks and 2.5% of the mined–out area.

Identification of the reasons of the mining block collapse, elucidation of the basic mechanism of this process, elaboration of the method of analysis and prognosis are the main aim of the presented work.

The potential prognosis methods for pillar and roof stability base on the following features:

1. The normal distribution control of the pillars cross–sectional area;
2. The rate of current rock strength;
3. Convergence curve;
4. Collapse time.

The paper deals with the prognosis method based on the statistical analysis of the pillars cross–sectional area. Normal distribution control allows determing the stability of a mining block. By normal distribution of the pillars cross–sectional area a potential collapse of a mining block can be expected. Method is applicable for practical purposes and gives excellent results. The land deterioration on the mined–out territories can be evaluated by the parameters of ground movement mechanism, using the conventional calculation schemes. The other methods are complicated and do not suit for practical application. They demand supplementary investigations.

2. Geology and mining

The commercially important oil shale bed is situated in the north–eastern part of Estonia. It streches from west to east for 200 km, and from north to south for 30 km. 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 oil shale reserves in Estonia are estimated approximately at 4 thousand million tons.

The oil shale seams occur among the limestone seams in the Kukruse Regional Stage of the Middle Ordovician. 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. The compressive strength of oil shale is 20–40 MPa and that of limestone is 40–80 MPa. The strength of the rocks increases in the southward direction. The volume density is 1.5–1.8 Mg/m^3 and 2.2–2.6 Mg/m^3 respectively. The calorific value of dry oil shale is about 7.5–18.8 MJ/kg depending of the seam and the area in the deposit.

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 (Fig.1). The oil shale bed is embedded at the depth of 40–70 m. The height of the room is 2.8 m. The room is very stable when it is 6–10 m wide. In this case, bolting must still support the immediate roof. The pillars in a mining block are arranged in a singular grid. Actual mining practice has shown that pillars with a square cross–section (30–40 m^2) suit best.

3. Theoretical background

Due to the complicated structure of the pillars and roof in Estonian oil shale mines, the stability analysis and prognosis demand special calculation methods. In general, the used methods are complicated (1,2). Statistical analysis and normal distribution control of the pillars cross–sectional area is suitable for practical application. Statistical analysis gives information about the quality of the performed mining works in a mining block. The normal distribution control of the pillars cross–sectional area allows determining the stability of a mining block.

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.

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It is known that if a measurement is subject to many small sources of random error, the measured values (pillar cross–sectional area) will be distributed in accordance with bell–shaped curve (3). It is claimed that a measurement subject to many small random errors will be distributed normally (Gauss distribution). The normal distribution control was made by kurtosis and skewness (4).

1. Kurtosis characterizes the relative peakedness or flatness of a distribution compared with the normal distribution. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution.
2. Skewness characterizes the degree of asymmetry of a distribution around its mean. Positive skewness indicates a distribution with an asymmetric tail extending towards more positive values. Negative skewness indicates a distribution with an asymmetric tail extending towards more negative values.

The load on the pillar depends on the stiffness of the roof and pillar (5). The roof in Estonian oil shale mines is enough stiff and in this case the bigger pillar receives the greater load. The failure begins from the bigger pillars. Consequently, the distribution of the cross–sectional area of the pillars determines the load on a pillar.

On the other hand, the pillar load depends on the width of the mining block, leading to the concept of the critical width. The critical width is the greatest width that the rock above the mine can span before its failure, or, if there are pillars, the width we must mine before the pillars accept the full weight of the overlying materials (6). Typically, full load comes onto the pillars closest to the center of a mining block. In fact, the best indicator of critical width in a given situation will be provided from old mine maps, by records of failures and surface subsidence, and from measuring roof–to–floor convergence in the mines. The critical width for Estonian oil shale mines is presented by the following formula (7,8):

$$L>1.2H+10,$$

where L – critical width, m; H – thickness of the overburden rocks, m.

In the three–dimensional case, the critical width transforms into the critical area.

The mining block stability depends on the real parameters of the roof and pillar. Consequently, in–situ conditions the pillar loads vary from place to place within a mining block. Investigation showed that the stability of a critical area determine the stability of a mining block Likely enough, the collapse begins in one critical area (potential collapse center) and then extends to the barrier pillars.

Normal distribution of the cross–sectional area of the pillars in a mining block is valid as well for critical area (4). It means that the normal distribution of the cross–sectional area of the pillars in a mining block determine the stability of a critical area. Take into consideration the above mentioned; it is visible that if a normal distribution is present in mining block or semi–block, then a potential collapse can be expected. Presented method does not determine the exact location and time of the collapse in a mining block.

The method suits well for mining block stability analysis and spontaneous failure prognosis. It is applicable for practical purposes. The surface subsidence parameters will be determined by conventional calculation schemes.

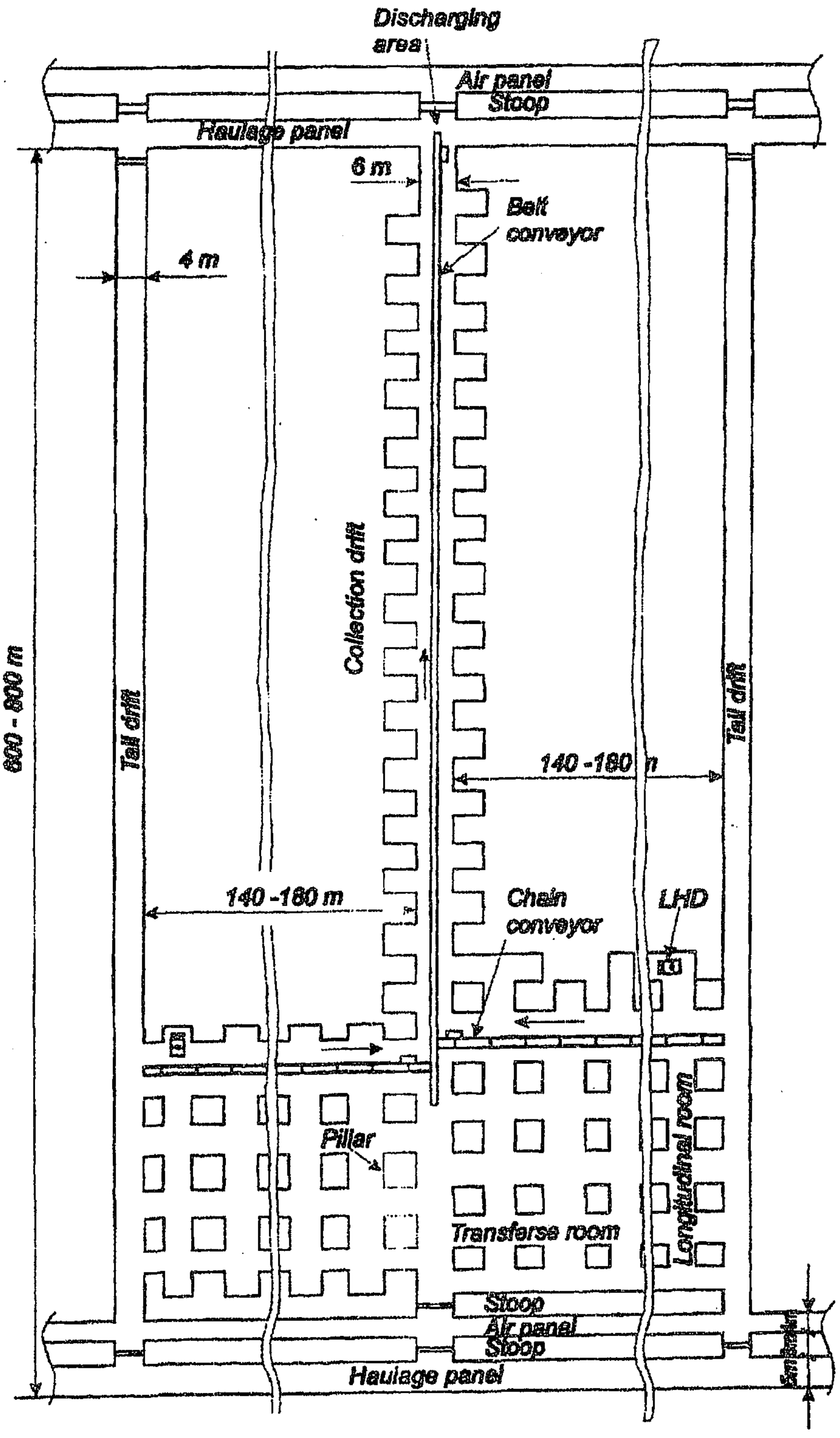

Figure.1. Schematic layout of room–and–pillar mining in Estonian oil shale mines

4. Results

The statistical analysis of the pillars was made for 12 mining blocks (the mines Ahtme and Estonia). The investigation results of the mining block No. 41 of the mine Ahtme and No.102 of the mine Estonia are given below.

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The statistical parameters and the results of normal distribution control of the pillars cross–sectional area are presented in Table.

Table

Statistical parameters of the pillars cross–sectional area.

Statistical parameters	Mine			
	Ahtme No.41 left semi–block	Ahtme No.41 right semi–block	Estonia No. 102 left semi–block	Estonia No. 102 right semi–block
Standard deviation	6.02	6.07	9.6	9.04
Kurtosis	0.40	0.38	8.5	6.90
Skewness	0.55	0.35	2.49	2.31
Normal distribution	YES	YES	NONE	NONE

Mine Ahtme, block No. 41

The commercial oil shale bed of the thickness of 2.8 m is embedded at the depth of 53 m. Barrier pillars border the mining block. The spontaneous collapse of the pillars in the left semi block took place 16 months after the beginning of exploitation. It reached the surface. The area of destructions was about 24 000 m^{2,} the age of the pillars being 3 to 9 months. The analysis shows that there is one center of a potential collapse. The age of the pillars in the center of the potential collapse was 8.5 months. Likely enough, the collapse begins in this center and then extends to the barrier pillars. Normal Distribution analysis shows that if a normal distribution is present in mining semi–block, then a potential collapse be expected (Table, Fig.2).

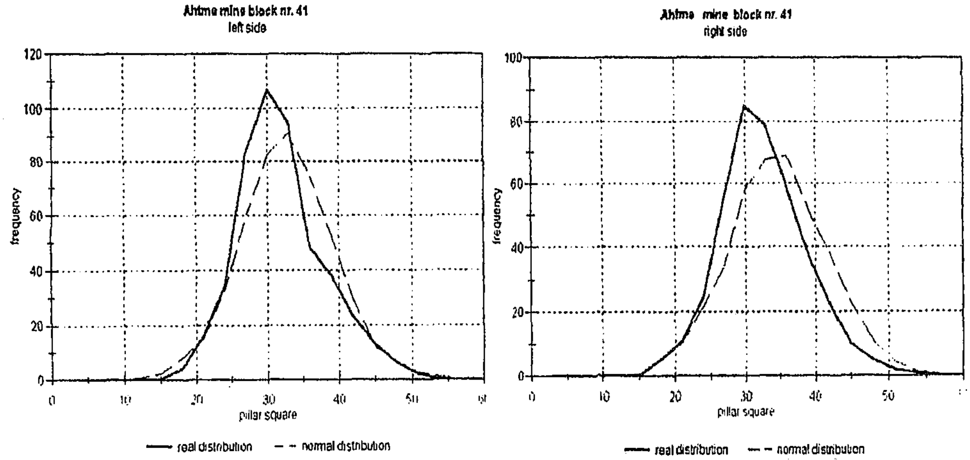

Figure 2. Normal Distribution control of the pillars cross–section area for the Ahtme mine semi–blocks

Mine Estonia, block No. 102

The commercial oil shale bed of the thickness of 2.8 m is embedded at the depth of 60,5 m. Mining block is bordered by barrier pillars. A spontaneous collapse and the normal distribution of the pillars cross–sectional area are not present in mining block (Table, Fig.3).

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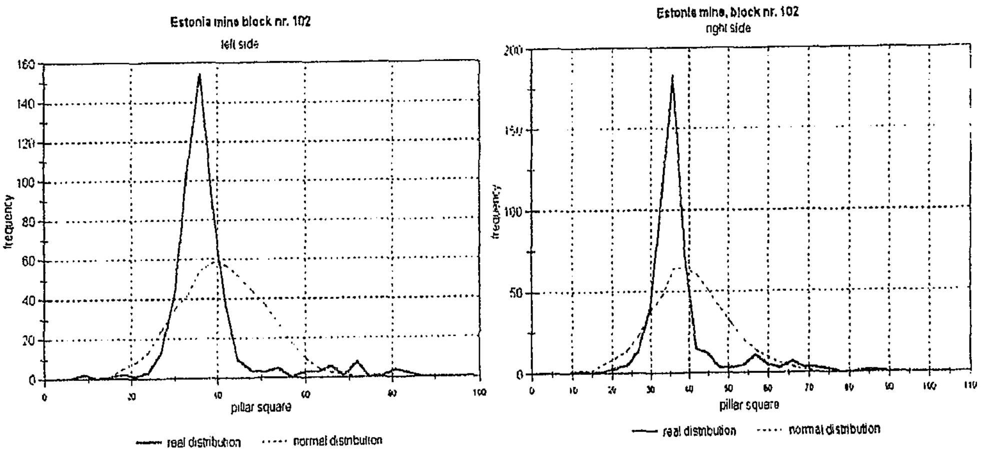

Figure 3. Normal Distribution control of the pillars cross–section area for the Estonia mine semi–blocks

The results of theoretical and in situ investigations in Estonian oil shale mines showed that they are close to the modeling results. The analysis was based on the geometrical parameters of mining blocks. Presented method does not take into consideration the rheological rock parameters. These problems demand supplementary investigations.

5. Conclusions and recommendations

As a result of this study, the following conclusions and recommendations can be made.

1. Estonian oil shale mines are located in a densely populated and intensely farmed district where the room–and–pillar mining method is used. The collapse of the pillars has caused the surface subsidence, which makes up 2.5% of the mined–out area.
2. Prognosis method based on the normal distribution control of the pillars cross–sectional area, which allows determing the stability of a mining block. It is applicable for practical purposes.
3. If normal distribution of the pillars cross–sectional area is present in a mining block, then a potential collapse can be expected. Theoretical and in situ investigations in Estonian oil shale mines showed that their results are close to the modeling ones.
4. The proposed method suits for stability analysis and failure prognosis.
5. Further investigations are aimed at the rheological and strength behavior of the rocks to determine the time and exact location of the collapse of pillars and ground surface.

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NOTEČU NO ORGANISKAJIEM MĒSLIEM SAMAZINĀŠANA
REDUCTION OF LEAKAGE FROM ORGANIC MANURE

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Abstract. *Environmental problems of leakage minimisation from solid manure handling in Latvia are discussed. Volume and composition of leakage from solid manure are investigated in storage period. Amount of plant nutrients in effluents are measured 0,099 kg nitrogen, 0,029 kg phosphorus and 0,381 kg potassium per tonne manure in 14–day period of accumulation and storage of solid manure in trailer. Plant nutrients losses in effluent from densely stockpiled manure are 0,40 kg nitrogen, 0,197 kg phosphorus and 1,372 kg potassium per tonne manure in 5–moth storage period while leakage were occurred. In first 2–month period nutrient losses are 74 % nitrogen, 54 % phosphorus and 54 % potassium of whole amount of losses in 5–month period. Proposed recommendations are aimed to minimise the leakage from solid manure in farms in Latvia.*

Keywords: *solid manure, manure effluent, pollution reduction*

1. Ievads

Viens no būtiskiem vides piesārņošanas avotiem ir noteces no kūtsmēsliem, kas nevērīgas uzglabāšanas rezultātā piesārņo gruntsūdeņus ar slāpekļa un fosfora savienojumiem. Slāpekļa zudumi no kūtsmēsliem var sasniegt pat 20 – 50 %, tādēļ noteču samazināšana ir nozīmīga kā no dabas resursu racionālas izmantošanas, tā arī no vides aizsardzības viedokļiem. Uzglabāšanas periodā ar noteci no katras svaigu kūtsmēslu tonnas vidē noplūst 0,14 – 0,26 kg slāpekļa [1]. Lauksaimniecības piesārņojuma samazināšanai Eiropas Savienība (ES) ir pieņēmusi Nitrātu direktīvu (EEC/91/676), kas būs jāpilda arī Latvijai, iestājoties Eiropas Savienībā. Helsinku konvencijas par Baltijas jūras vides aizsardzību (HELCOM) pieņemtie līdzīga rakstura pasākumi (HELCOM Rekomendācijas 7/2, 9/3 u.c.) Baltijas jūras piesārņojuma samazināšanai jau kopš 1992. gada ir saistoši Latvijai kā konvencijas dalībvalstij. Piemēram, HELCOM Rekomendācija 7/2 iesaka veidot monitoringu augu barības vielu zudumu kontrolei un veikt lauksaimnieciskās ražošanas metožu ietekmes uz vidi zinātnisko izpēti. Lielākajai daļai no Latvijas mazajām fermām nav ierīkotas kūtsmēslu krātuves ar šķidrumu necaurlaidošu pamatni, pie kam daudzām kūtīm nav vircas uzkrāšanas tvertņu. Notecēm nonākot gruntsūdeņos, nereti pasliktinās dzeramā ūdens kvalitāte akās. Piemēram, no apsekotajām astoņpadsmit Zaņas pagasta zemnieku saimniecību dzeramā ūdens akām slāpekļa koncentrācija sešās un fosfora koncentrācija divās akās bija augstāka par pieļaujamo. Noteces no kūtsmēsliem veidojas no svaigos kūtsmēslos esošā gravitācijas šķidruma (masā neuzsūktais un gravitācijas spēku ietekmē notekošais šķidrums) un no kompostēšanas procesā radītā šķidruma summas. Racionāla kūtsmēslu uzkrāšana ar palielinātu pakaišu devu un to kompostēšana krātuvē var samazināt vai pat novērst piesārņojošo noteču noplūdes gruntsūdeņos. Īpaši aktuāla minētā problēma ir nelielām un vidējām (līdz 5 mājlopu vienībām) saimniecībām, jo tām šobrīd netiek paredzēta prioritāte subsīdiju saņemšanai modernu kūtsmēslu krātuvju būvei vai progresīvu šķidrmēslu

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