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TESTING OF GEOMECHANICAL PROPERTIES OF COAL SERIES IN ORDER FOR SUPPORT DETERMINATION OF THE MECHANIZED STOPE ON THE EXAMPLE OF "STARA JAMA" MINE IN "LUBNICA"

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Abstract

Problems presented in this paper are dedicated for definition the impact of geomechanical properties of coal series in order to determine the rational parameters of constructive support for mechanized stope , on the example of "Stara jama" mine "Lubnica“ - Zaječar.

The main direction of mining system development of coal deposits aims to mechanized longwall face. The most influential conditions for successful work are natural-geological conditions of deposit. From complex of influential factors that define the conditions of exploitation, and determine the technical-economic and security settings is separate segment of geomechanical properties of working environment, and all necessary researches and testing have done.

For defining the impact of geomechanical properties here were used systematic methods of data analysis on working factors in the mines with similar conditions, and for the analysis of the primary state of stress and deformation is applied mathematical modeling using finite elements. The results can be used in other coal mines with similar conditions of deposits in Serbia and abroad.

Key words: *underground mining, longwall face, system of underground mining, coal, modelling.*

1. Introduction

Excavation is the main phase of the exploitation of coal, which mostly affects on the other phases, subordinated them to the ultimate goal. Security, technical and economic efficiency of mining method greatly depends on way of excavation.

Excavation of coal layers by mechanized longwall face system requires a high degree of research and definition of natural-geological conditions of deposit. Especially important is the definition of stress and deformation in the vicinity of stope and access facilities, in terms of defining their stability. Besides this,

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geomechanical properties of coal seam, floor and roof have decisive influence in terms of selection and application of the process of managing the immediate roof.

In the rational choice of mining in our underground mines have a decisive influence of present conditions of exploitation, which are due to significant differences in the geological age and intensive tectonics in place (Tertiary deposits of coal instead of carbon) differ from other mines in the world that we take the machinery for excavation.

It can be noted that our mines are in relatively difficult conditions for the operation, with significant changes from deposit to deposit, and often between panel sides in deposit. These changes come especially to express as the exploitation works go in depth.

Since the natural-geological conditions cannot be directly affected, the technical-technological conditions of mining are subject of researches and study. Adequate selected methods and mining technologies, the best mechanism for obtaining construction and transportation, the choice of type and mode of support and managing of the roof, and organization of work are a number of potential opportunities for improving the mining effects.

Natural deposits are the basis for the selection of technical solutions in this part of the plant and equipment for all technology operations and require a permanent working phase adjustment of the regime and conditions of the working environment. In order to identify the real links and relations between natural conditions, characteristics of basic equipment and production capacity it starts from the cycles of production, and basic technological operations, as integral elements of the production cycle. In brown-lignite coal mine "Lubnica" is present the evident decline of production, backwardness in technological development and financial losses in business, which leads to the question of mining justification. In order to overcome the complex problems of the research carried out the possibilities of mechanized stope application.

Researchers have shown that the specific conditions may apply mechanized excavation by short mechanized stope, which is now, considering applied pillar methods, of significant progress in the production, economic and security terms.

2. Researches of working environment conditions

On the basis of thoroughly performed analysis of natural-geological conditions on the choice of mining system (methods and technologies), it has developed proper systematization (Table 1) and Table 2 shows the influence of the rank of general natural-geological conditions on the choice of mining [1].

The subject of the research is the coal seam in the "Stara jama" pit, which characteristic profile is shown in the Figure 1. Coal area of the mine "Lubnica" belongs to Lubnica - Zvezdan tertiary basin, of about 14 km and with confirmed 12 million tons of brown-lignite coal reserves. Coal horizon is essentially built of marlstone with partially present of slate and sandstone parting.

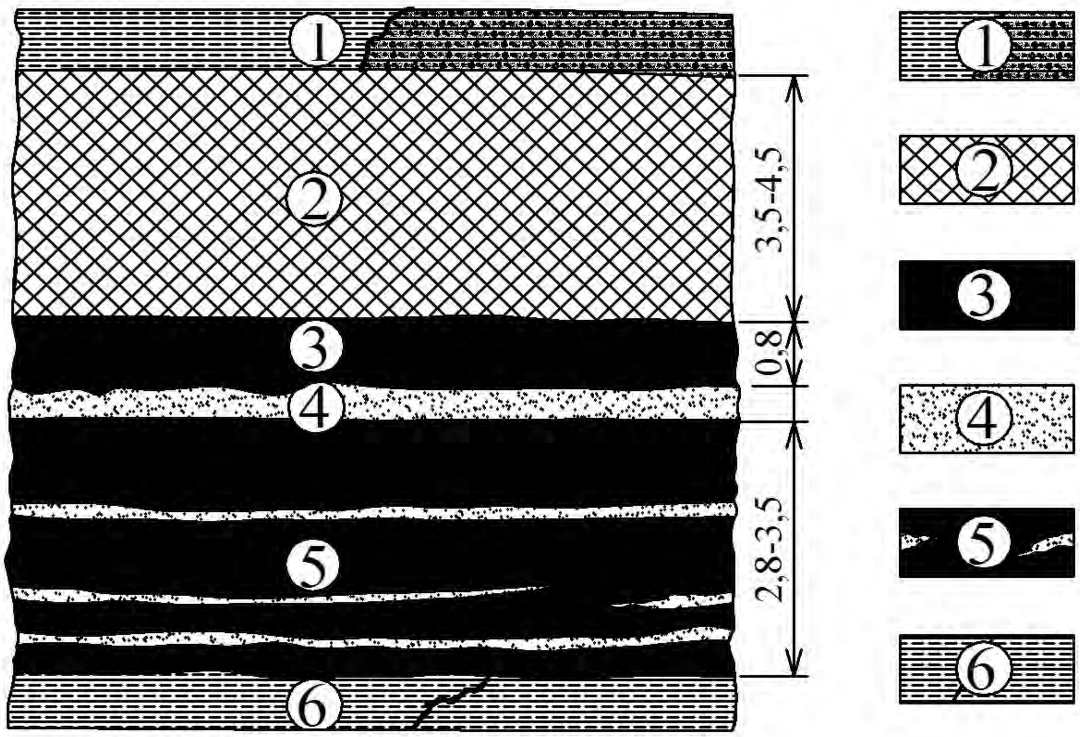

Figure 1. Geological structure of the first coal seam; 1. Roof marls tuff sandstone and tuff micro conglomerate, 2. Excavated roof part of the coal seam, 3. Roof part of the coal seam functioning as a protective slate, 4. Main thin seam of the tuff sandstone, 5. Unexcavated floor part of the coal seam, 6. Laminated lime sandy alevrite floor sandstone

Upper parts of Helvetica coal series are clayey-sandstone composition in which is dominant non-stratification clay, sandy clay and clayey sandstone.

Coal layers slope varies from horizontal up to 25 degrees, and rarely over 35 degrees. Tectonics is expressed and affects the dimensions of the field by direction and fall.

Immediate roof is made of fine-grained tephrite sandstone layer thickness from 0.3 to 0.5 m, and above it is a coal plate thickness from 0.5 to 0.8 m above the old work previously mined roof part layer. Direct coal layer floor is made of sand and marl sandstone.

In figure 2 is shown the systematization of natural and geological conditions that affect on the choice of mining.

The following tables 1 and 2 contain categorization of influence of natural – geological conditions on the choice of mining system.

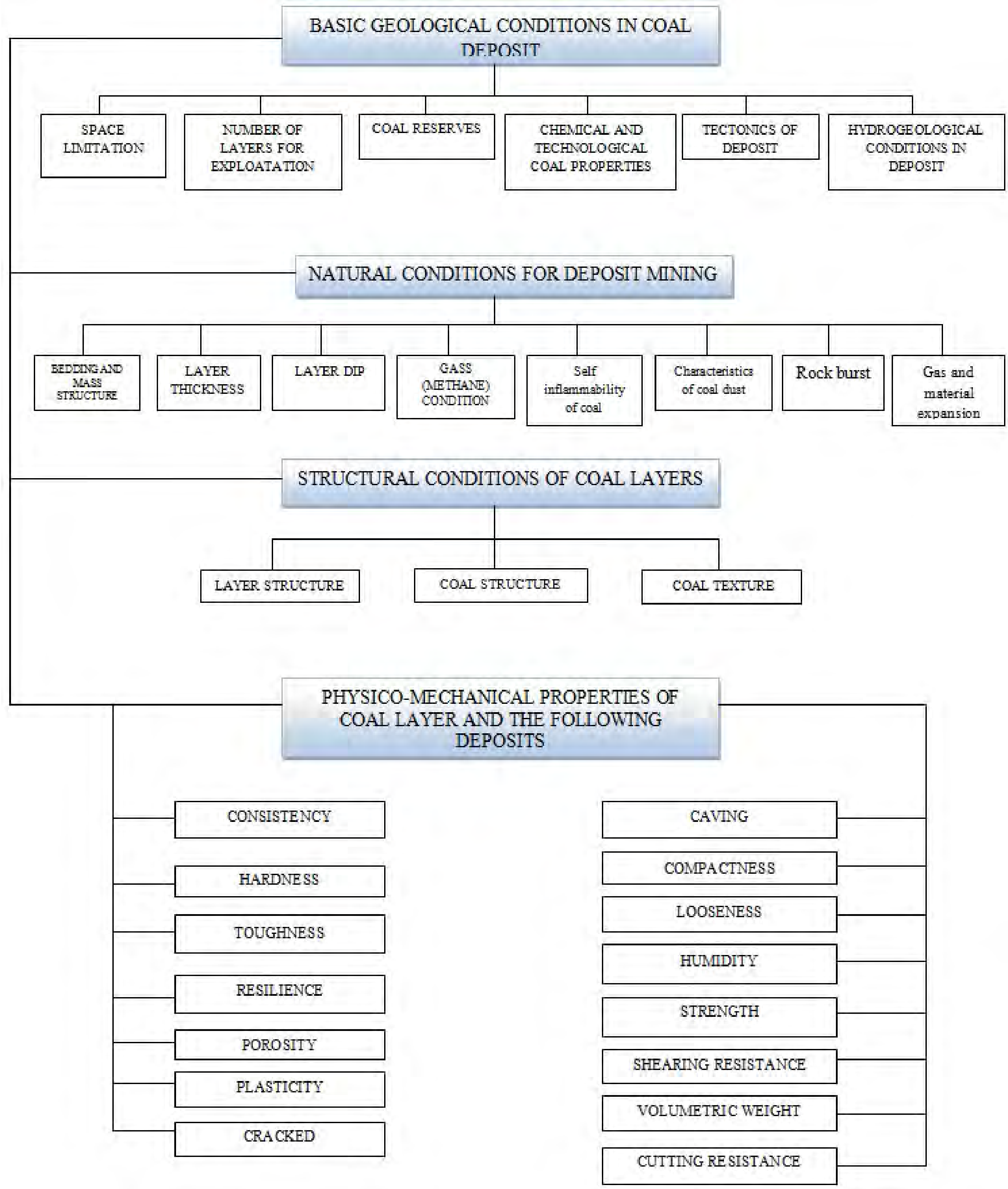

Figure 2. Systematization of natural and geological conditions that affect on the choice of mining

Table 1. Category – rang of influence of natural – geological conditions on the choice of mining system

MINING SYSTEM		CATEGORY – RANK OF INFLUENCE OF NATURAL-GEOLOGICAL CONDITIONS	
		I GOVERNING	II ADDITIONAL
MINING PRINCIPLES	HK	1. layer thickness up to 5m	2. layer gradient
	VK	1. layer thickness over 5m	2. layer gradient
MINING METHOD	Long wall face (HK)	1. layer thickness up to 5m 2. rational mining field length by dip and strike	1. layer dip 2. physical-mechanical properties of layer and following deposits 3. layer thickness changes
	Long wall face (VK)	1. layer thickness over 5m 2. rational mining field length by dip and strike	1. layer dip 2. physical-mechanical properties of layer and following deposits
	Chamber method	1. layer thickness over 5m 2. strength and compactness of direct roof	1. layer thickness and dip changes
	Pillar method	1. layer thickness over 5m 2. rational mining field length by dip and strike	1. layer dip 2. physical-mechanical properties of layer and following deposits
MINING TECHNOLOGY	Blasting	1. physical-mechanical characteristics of coal layer	1. layer thickness
	Cutting	1. physical-mechanical characteristics of coal layer	1. layer thickness
	Scraping	1. physical-mechanical characteristics of coal layer 2. layer thickness	1. physical-mechanical characteristics of the floor
	Cutting off	1. physical-mechanical characteristics of coal layer	1. layer dip 2. physical-mechanical characteristics of the floor
	Hydro destruction	1. physical-mechanical characteristics of coal layer	-

Table 2. Category – rang of influence of natural – geological conditions on the choice of mining system

MINING SYSTEM		CATEGORY – RANK OF INFLUENCE OF NATURAL-GEOLOGICAL CONDITIONS	
		III LIMITING	IV EXCLUSIVELY
MINING PRINCIPLES	HK	3. rock burst 4. gas and material expansion	-
	VK	3. tendency of coal to self inflammability	1. layer thickness less then 5m
MINING METHOD	Long wall face (HK)	1. high coal-seam methane content 2. size of coal reserves 3. physical-mechanical characteristics of floor	1. irrational mining field length by dip and strike
	Long wall face (VK)	1. abundant in water 2. tendency of coal to self inflammability 3. high coal-seam methane content 4. size of coal reserves	1. irrational mining field length by dip and strike
	Chamber method	1. layer dip 2. high coal-seam methane content 3. tendency of coal to self inflammability	1. bad size of strength and compactness of direct roof 2. rock burst
	Pillar method	1. layer dip 2. high coal-seam methane content 3. tendency of coal to self inflammability 4. rock burst	-
MINING TECHNOLOGY	Blasting	1. properties of coal dust 2. high coal-seam methane content 3. coal layer structure	Selection of the appropriate mining technology (alternatively, a combination of two or more technologies)is conducting according to the principles of mining methods and governing factors
	Cutting	1. coal layer structure	
	Scraping	1. coal layer structure	
	Cutting off	1. layer dip over 25 degrees 2. coal layer structure	
	Hydro destruction	1. coal marked tendency of self inflammability	

3. Researches results of geomechanical properties of coal layer and the following deposits

Testing of geomechanical properties are performed in the Laboratory of geomechanic, Mining and Metallurgy Institute, in small samples, methods that are standardized for each type of testing in the mining to the recommendations of the International Society for rock mechanics (ISRM). All necessary investigations are carried out in such number of samples that the results obtained on the basis of certain secondary properties, for each investigated interval. The average value of the investigated properties is the formula to count the standard deviation and coefficient of variations of the middle item. Tables 3, 4 and 5 present the researching results of coal layer properties and accompanying rocks (physical, mechanical and deformation and technical properties).

Table 3. Physical properties of the floor part of „Lubnica“ coal seam

Lithologic unit symbol	Volumetric weight in (KN/m^3)	Water content V (%)	Longitudinal wave velocity B_1 (m/s)	Transverse wave velocity B_1 (m/s)
Immediate roof	15,04 K_{var}=2,53%	20,22 K_{var}=2,53%	1476 ⊥ 1698 II	
Coal seam	12,45 K_{var}=2,53%	36,13 K_{var}=2,53%	1709 ⊥ 1898 II	760 ⊥
Floor board	16,62 K_{var}=2,53%	21,62 K_{var}=2,53%	1290 ⊥ 1685 II	
Immediate floor	16,87 K_{var}=2,53%	26,60 K_{var}=2,53%	1379 ⊥ 1815 II	

1.

Table 4. Mechanical properties of the floor part of „Lubnica“ coal seam

Lithological unit symbol	Monoaxial pressure resistance on σ_n (MPa)	Tension resistance σ_x (MPa)	Bending resistance σ_f (MPa)	Cohesion C (MPa)	Internal friction angle φ^o
Immediate roof	8,11	0,79	3,18	1,25	38
	K_{var}=15,12%	K_{var}=11,73%	K_{var}=16,65%		
Coal seam	19,48	2,01	4,65	2,90	35
	K_{var}=8,99%	K_{var}=7,29%	K_{var}=15,81%	K_{var}=10,24%	K_{var}=7,10%
Floor board	7,21	0,69	4,86	1,23	33
	K_{var}=7,55%	K_{var}=8,35%	K_{var}=6,23%		
Immediate floor	9,32	0,87	4,98	1,78	36
	K_{var}=8,53%	K_{var}=13,10%	K_{var}=18,83%		

Table 5. Deformation and technical properties of the floor of „Lubnica“ coal seam

Lithologic unit symbol	Tangent modulus E_t (MPa)	Secant modulus E_s (MPa)	Deformation modulus during breaking E^1_d (MPa)	Poison coefficient V	Resistance		Crushability coefficient f
					KL, ⊥ (N/cm^2)	KF, ⊥ (N/cm^2)	
Immediate roof	480	270	240	0,21	383 K_{var}=8,84%	58 K_{var}=13,78%	
Coal seam	614 K_{var}=8,39%	325 K_{var}=8,55%	325 K_{var}=7,29%	0,33 K_{var}=10,22%	1536 K_{var}=12,25%	211 K_{var}=15,33%	7,99 K_{var}=15,33%
Floor board	519	330	318	0,36	510 K_{var}=13,62%	65 K_{var}=14,68%	
Immediate floor	535	330	319	0,27	600 K_{var}=21,37%	99 K_{var}=8,66%	

4. Research of stress – deformation condition in rock massif around mechanized workings

The main problem in determine the equipment for mechanized workings is selection of support elements that is SHP section.

There are several approaches in solving the problem of correct selection of necessary SHP carrying capacity for specific conditions. One of the approaches is selection of SHP the reaction of which will prevent excessive convergence.

Another approach is based on selection of support with as great reaction as possible, which would completely prevent separation of seams in the area above the face. Limiting factor in the latter approach is pressure on the floor and roof, which must not exceed hardness of the immediate floor and roof. Geo-mechanical considerations during SHP dimensioning are related with selection of reaction magnitude by which the support resists the open roof, and also with selection of loading during relaxation. Inappropriate stressing force may cause excessive convergence, which is head roof breaking. Too big stressing force may cause breaking of roof and floor rocks. Complexity of massif management with mechanized excavation is shown, among other things, in necessary stability of the roof plate in front of the support, and in its good breakability behind the support. In most cases, coal is the hardest and most tenacious rock in productive series, therefore the problem amounts to determination of roof plate thickness as a function of set requirements. In specific case of the first seam of “Stara jama” pit the problem became even more complex with previous excavation of the upper part of the seam. The roof part of the seam which was previously excavated is separated from the floor part by the seam of 0,4m thick tuff sandstone. During excavation of this roof part of the seam, a 0,8m thick plate was left above the sandstone. The floor part of the seam which is prepared for working is 2,8 – 3,5 thick. Since the thin seam of sandstone is not sufficient hard, research is directed towards determination of coal plate thickness under the thin seam of sandstone, which will provide stability of excavation in front of the support. The problem is solved with numeric models of finite elements using Phase 2 software (2D finite element program for calculating stress and estimating support around underground excavation), Rock Engineering Group, University of Toronto [2]. The basic model of finite elements on which the research was carried out is given in Figure 3.

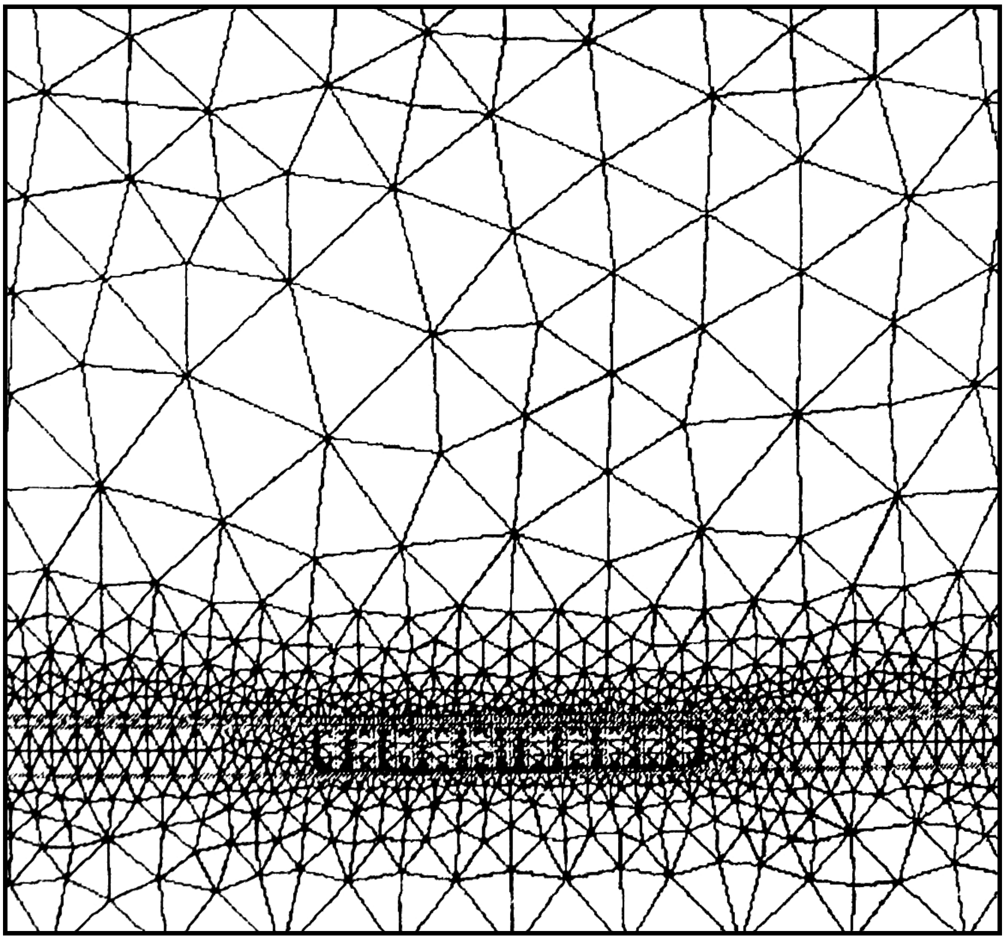

Figure 3. Look of the finite element basic model

During research this model was transformed in about ten separate models and excavation in mine phases was simulated in each. A 0,3m thick coal seam was modeled. During excavation, a 0,3m thick floor plate was anticipated, and roof plate thickness was variable (0,3; 0,5; 0,8m). Excavation pace of advance is 1m, and maximum unsupported range in front of the support is 2m.

Coal disintegration in one of an excavating machine is modeled. The finite element method is used with numeric method modeling and elastic-ideal plastic model for rock massif with Mohr-Colombus material.

The 0,3m thick coal plate under roof sandstone was modeled first, based on real engineering experience and preliminary model research. After a certain number of excavation paces after fracture of the roof plate behind the support, progressive fracture and breaking of surface rock massif occur. Soon after the roof plate in front of the support is breaking gradually. The seam of sandstone is broken first, than the 0,5m and 0,8m thick coal plate is broken, during which time the complete simulation of excavation is carried out on several consecutive models (Figures 4 - 7).

The figures present isolines of safety degree with markers of broken elements. Markers in the shape of dot show that the marked element is broken due to extension load, and markers in the shape of cross show that breaking occurred due to shearing. Plastification zone is above the support in goaf as Figures show, whereas both coal plates, even sandstone show satisfactory stability.

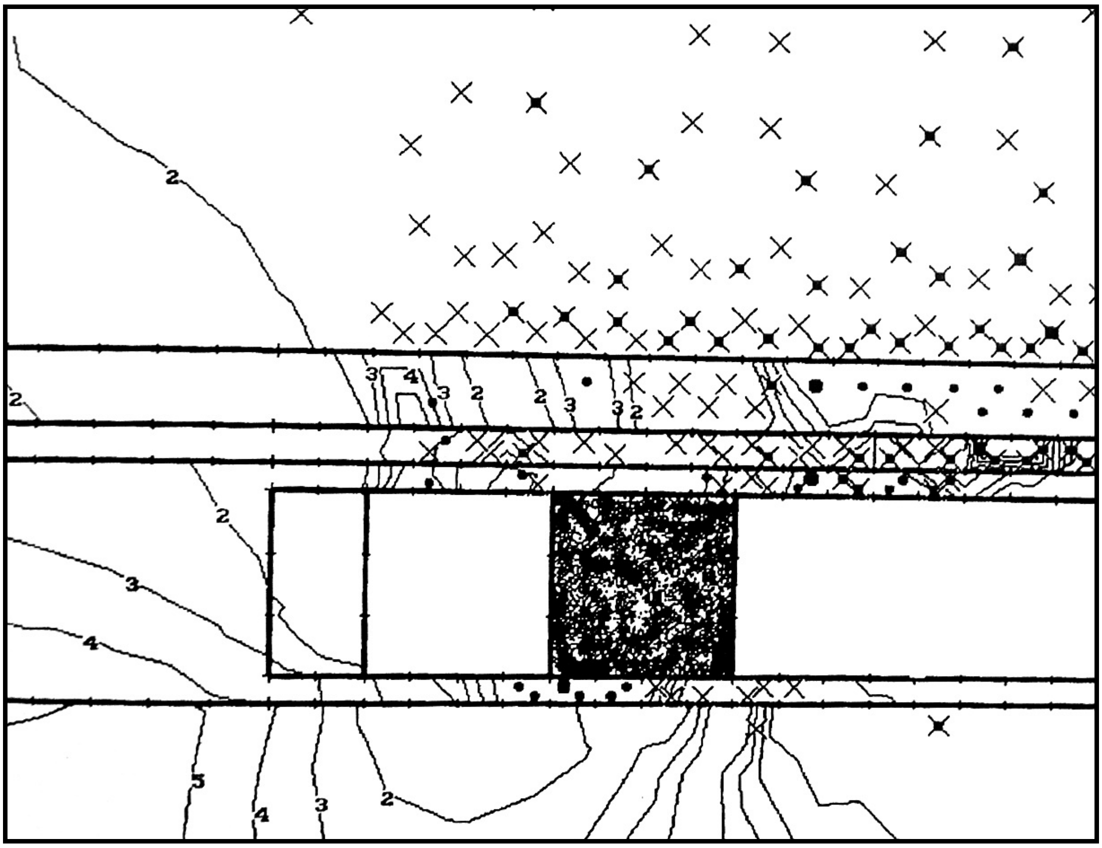

Figure 4. Graphic illustration of 0,3m thick roof plate stability condition

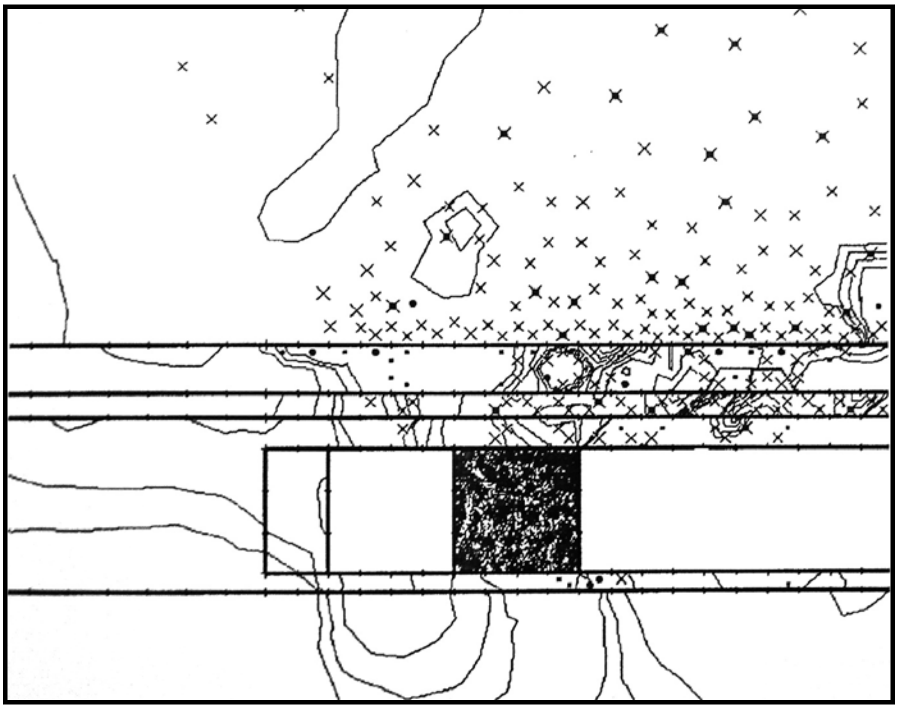

Figure 5. Graphic illustration of 0,5m thick roof plate stability condition

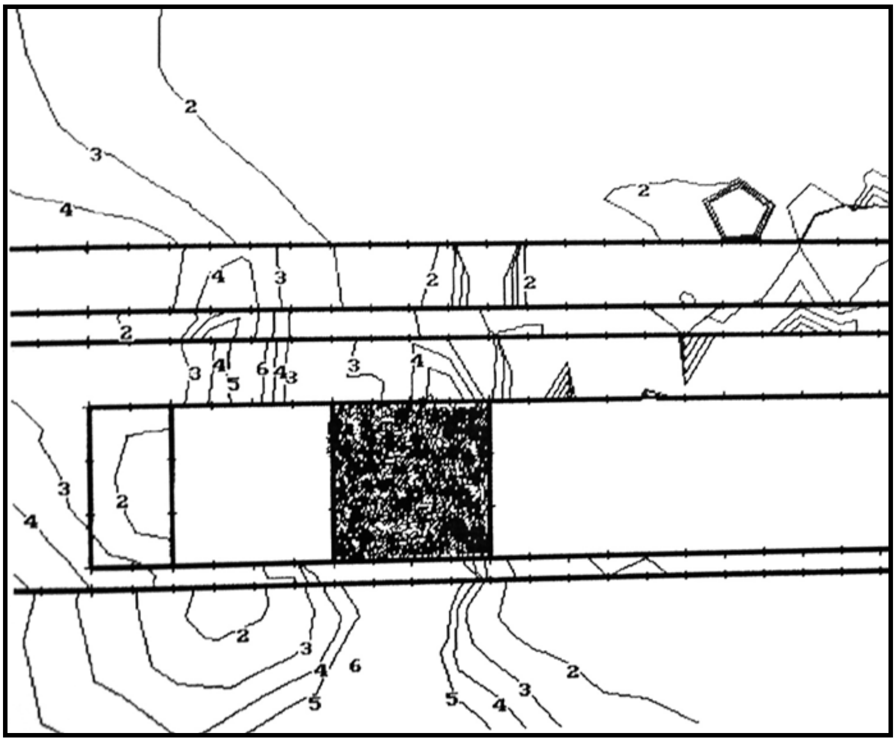

Figure 6. 0,8m thick roof plate stability condition isolines

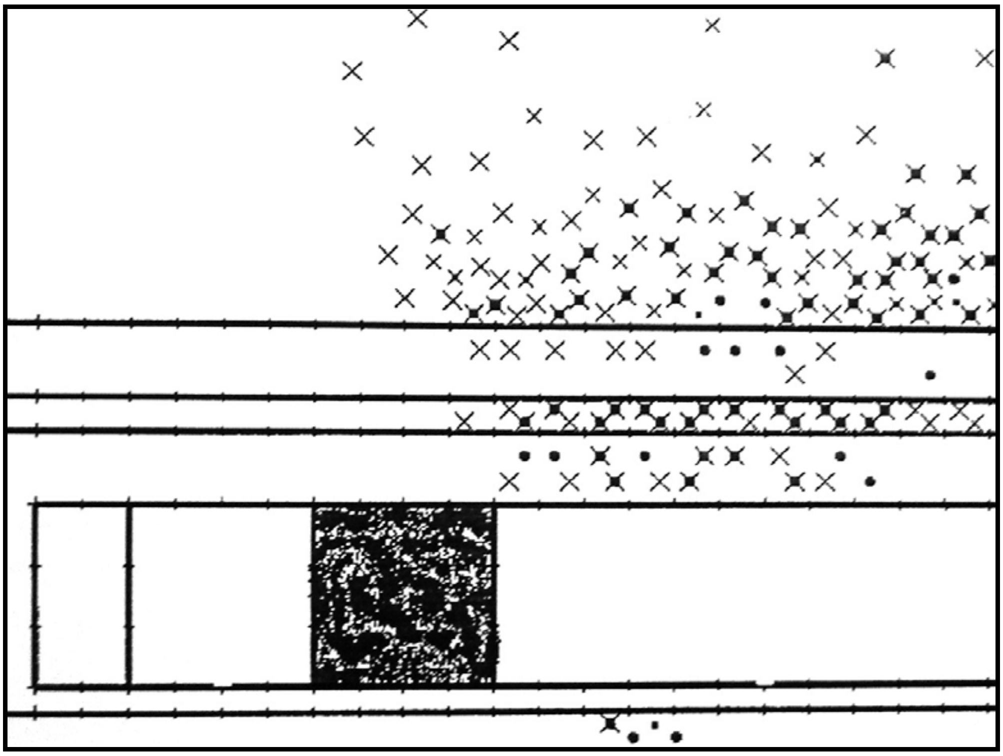

Figure 7. 0,7m thick roof plate plastification zones

According to calculated stress values in front of the face, maximum stress concentration is 10,65 MPa, therefore at 10m from the face towards massif goes for primary stress condition value of 2,75 MPa. To 1,5m in front of the face, dirt band which is located in the roof between two coal plates, will be crushed, therefore maximum bearing pressure will be at 1,5m in front of the head with value of about 8 MPa. Calculated required resistance force of the frame type support is F=1,37 MPa, whereas with shield support, depending on the shield type, it amounts to 1,5 – 2,5 MPa on the roof.

Application of two-prop retaining – shield support is adequate according to physical, mechanical, deformation and technical properties of the coal seam.

The investigated floor part of the first coal seam belongs to hard brown – lignite coal with pressure strength of σ_{prs} = 19,48 MPa and with expressive modulus deformability E_t = 614,0 MPa. Required cutting cutting force is K_l = 1536 N/cm^2 and cutting resistance K_F = 211 N/cm^2, therefore the coal seam belongs to coal that can be excavated easily with a loader. Stress and deformation analysis using finite element method with 0,3; 0,5 and 0,8m thick coal plate model in the face roof, indicates that the 0,3m thick is unstable flakes easily.

5. Conclusion

On the basis of performed environment condition investigations, it is established that mechanized excavation by utilization of SHP for support of excavation working space and of excavating machine with cutting technology, can be applied, in specific case of the floor part of the I coal seam in “Stara jama“ – Lubnica.

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