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THE RESULTS OF AT ROOFBOLTING SYSTEM OF SUPPORT APPLICATION IN "SOKO" UNDERGROUND MINE

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ABSTRACT

Complex mining and geological conditions of coal exploitation, such as the Soko mine, requiring the constant work on the research of new technical solutions of development and supporting of the underground openings.

In this paper presented detailed description of the existing way of development and support underground openings at the mine Soko.

Experience in the current method of development and supporting of the openings showed a number of disadvantages especially in terms of increased underground pressures that have affected the deformation of underground openings.

Installing AT roof bolting system of support and test support in the drift EH- (-60) z in the underground mine Soko with the combined support represent the new solutions of development and support and function of the increasing stability of mining facilities, extending the life of their exploitation and functionality.

Keywords: *underground pressures, mining facilities, support, steel support, anchors*

INTRODUCTION

One of the main problems in underground coal exploitation is the stability of underground openings and other mining facilities because the finding of the optimal solutions of development and support the underground, basic excavation and preparation have a special importance and impact on specific investments [1,2].

In addition to stability of the underground mines for manufacturing system is a very important and timely production of facilities in order to maintain continuity of production in the process of production by introducing the new excavation units [3,4,5].

In order to exceed of these problems and correct choice of development technology and support of openings at the Soko mine has been done on the introduction of new technology, whose main goal is the improvement of the general conditions of underground openings and improvement of quality, of support and thus increasing their working life, as and create conditions for a more secure and safer operation [6].

The previous considerations and experience of stress, indicate that the mining facilities in the Soko mine are exposed to the intense of the pressures and deformations, and therefore reduces their useful exploitation. [7]

By technical documentation related to the trial support in the underground openings EH- (-60)z in mine Soko by combined support is defined the parameters and activities related to the introduction the new supporting technology by AT roof bolting system of support in underground mine Soko.

THE COAL CHARACTERISTICS AND SURROUNDING ROCKS

In coal deposit Soko within coal horizon there is a coal layer of high quality with complex structure due to the presence of thin seam of dark- gray marl - sandy clays with freshwater fauna and white marls. In the foot and floor of coal seam are dark- gray partly carboniferous clays or marl with bands of coal. The main coal seam develops to the whole deposit. The thickness of the carbon layer was in the range of 20-35 m with incline of 25°-40° to the north, and near the faults incline of seam can be much higher. Roof of coal seam is composed with marl, sand and shale clay and shale, clay and shale weakly bound sandstone and sand, gravel in places. In some parts of the deposit developed the one and sometime two roof coal layer thickness from 0.5 to 3.0 m. In the seam of coal seam developed marl, in some cases marl and argillaceous limestone with a variable content of $CaCO_3$.

THE PHYSICAL AND MECHANICAL CHARACTERISTICS OF COAL AND SURRONDING ROCKS

Testing of physical- mechanical properties of rocks were carried out on the samples from the coal seam and direct floor and roof of coal seam, 1974/75 year. These studies showed that some parts of the coal seam and intermediate rock in coal seam have the different values of the investigated parameters. Roof sandstone under the influence of water loses their cohesion and roof argillite saturated by water have characteristic from lean to fat clays with high plasticity.

The floor argillites in contact with water take on the characteristics of fat clays with high plasticity. Table 1 presents the data of physical- mechanical properties of coal and surrounding rocks of the coal deposit Soko.

Table 1 Physical and mechanical properties of coal and surrounding rocks on Soko deposit

Lytology	γ_S g/cm^3	γ_r g/cm^3	W %	n %	σ_c daN/cm^2	σ_i daN/cm^2	σ_s daN/cm^2	σ_r daN/cm^2	C daN/cm^2	φ ^{0}
Marl and limestone in roof	2,51 2,58 2,47 1,12	1,68 1,83 1,44 2,24	23,03 32,90 10,55 5,55	32,93	124,6 140,7 108,0 15,12	42,46 152,9 12,25 12,46	36,08 48,17 30,92 11,74	25,50 28,36 18,91 29,20	41	33
Coal	1,37 1,38 1,35 1,03	1,32 1,33 1,32 0,53	30,29 30,48 29,48 1,64	3,65	290,2 324,7 236,3 12,93	21,0 26,04 10,23 35,06	58,8 70,71 46,62 17,25	55,04 61,57 44,78 13,25	36	38
Clay coal	1,65 1,66 1,65 0,51	1,48 1,52 1,44 7,25	25,60 27,28 29,39 7,45	10,57 12,72 8,43	155,2 198,4 111,9 36,61	24,07 28,50 16,65 12,52	15,43 23,31 7,25 22,96	19,95 32,34 15,29 18,72	28 29 26	33 35 32
Clay and argillite	2,50 2,57 2,41 2,04	2,19 2,35 2,05 0,88	7,73 9,81 6,42 7,63	12,81 14,96 8,56	83,64 90,6 76,18 14,70	9,45 11,3 9,61 17,64	5,74 7,28 4,51 45,16	13,47 18,64 10,65 21,25	16,6 22 14	32 33 31
Sandstone	2,65 2,70 2,61 0,56	2,32 2,47 2,17 2,08	5,38 5,81 4,93 5,60	12,68 16,85 8,52	93,60 110,9 76,9 33,17	10,72 19,10 2,34 21,24	15,69 27,66 3,73 30,57	14,67 25,84 3,47 28,60	24	26

PRESENTATION OF CURRENT SUPPORT SYSTEM IN THE UNDERGROUND OPENING IN SOKO MINE

Working environment in the mine Soko are mostly marl sandstones in roof and less extent of coal and marl (roof and foot), and carboniferous sand and clay. Mining facilities at the mine through the long period of exploitation were made through all kinds of rock material.

The underground openings are partly supported by roof steel frame support by type ZO – 3 and partly by steel frame support by type KOP. Support by type KOP is represented in two ways, depending on the type of profile, KOP29 and KOP21.

Circular steel support applied in two dimensions of the cross section 3.5 m cross section area is 9.62 m^2 and ∅ 4.0 m section, section area 12.56 m^2.
The supports concrete is applied to support of haulage shaft and ventilation shafts and their shaft landing.

The new designed openings (New Soko), the main transport slope in coal GTN are supported by roof type K -24 and reinforced pledger. Profile of the openings of approximately 17 m^2 is made in the arc support.

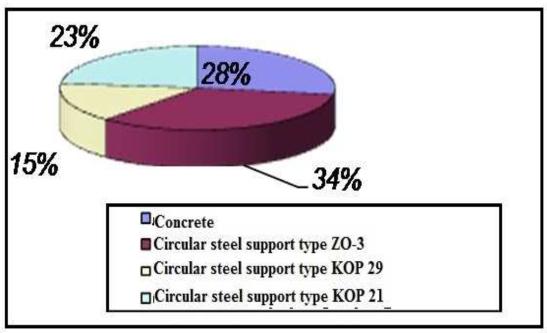


Figure 1 Classification of support

APPLICATION OF NEW TECHNOLOGIES IN SUPPORT OF EXAMPLE ON DRIFT EH- (-60) Z

Description, calculation, choice and the manner of steel support steel in the underground is done according to the prescribed methodology and practice for the underground coal exploitation.

The initial activity of the first phase of the technology requires the choice of location of mining facilities at which was done a detailed study of rock massif in the previous period. Profile coal seam in RMU Soko, which is shown in Figure 2 made on the basis of technical documentation and in consultation with the geological survey of mine. [8]

Trial support of drift EH (-60) z in the underground mine Soko is the starting activity of application the supporting technology by AT roof bolting system of support.

AT anchors belong to the group of anchors that contact with the rock massif realize to the full length of the borehole and in principle, can be used in all of the work environment, with different effects. Effect of AT roof bolting system of support is based on principle of preventing the contour deformation of layers to underground chambers and to prevent the deformation in fractured zones and while partially filled the cracks.

In this way creates the zone of increased massif around underground opening. It can be said that AT roof bolting system of support is active, or to enter into effect before the contours of the underground structure deforms. Compared to AT anchors, steel support is a passive support or receives the loads after deformation of the stope contours.

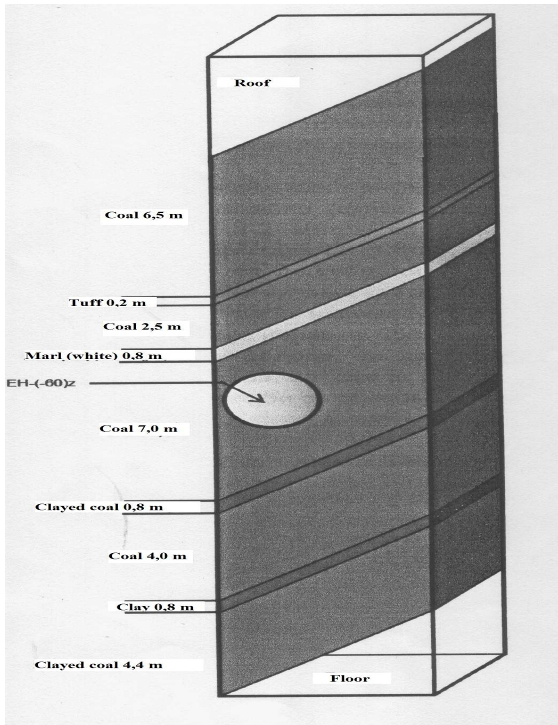


Figure 2 Geological profile of coal seam in the underground mine Soko and the drift EH- (-60) z position

The environment in which it is incorporated AT anchors, or the immediate environment qrround the underground excavation, can be seen as a mean to changing physical and mechanical properties, which is of particular importance because in these areas creates a stress concentration (in floor and sides) which causes deformation of contours of underground opening [9].

The possibilities and effects of AT roof bolting system of support tested and determined only experimentally or by trial supporting.

Experimental verification consists the three phases:

Phase I testing of location and preliminary research,

Phase II Systematic trial support;

Phase III Certification of adopted solution.

As a location for a trial supporting in underground mine Soko is selected underground excavation drift EH- (60) z, which will be carried out during the first phase of testing and preliminary research. The activities under the first phase are:

- Verification of roof characteristics, which present the identification of all the seams and thin seams in the roof of underground chamber and in an amount that is twice higher of anchoring, made on the basis of existing studies [10].

- Test installation of AT roof bolting system of support elements includes activities that determine the suitability of equipment for drilling of anchor holes and installing anchors in concretely working conditions, with key indicators: speed drilling, borehole profile.

Hole diameter is an important characteristic that affects the effectiveness of AT roof bolting system of support, as in situations where the installation of small diameter of anchors hole done with difficulty, whereas a large diameter adversely affect the overall strength of relation anchor - mixture – rock mass, due to higher volume of hole. Anchors are made of ribbed steel reinforcement, strength of 650-700 MPa (tensile strength 800-850 MPa). Diameter of 23 mm and standard lengths: 1.5, 1.8, 2.1 and 2.4 m.

Binary mixtures are the basis of this system of support. These mixtures packed in a cartridge diameter of 24 mm, and the standard length (mm): 225, 350, 450, 600, 800, 1050 and 1250. The composition according to the time of solidification can be

- Rapid solidification, and
- Slow solidification.

Binary mixtures are related the two qualities that are very important for their installation and reliability of the system of support. These are: the time (period) to solidification (Gel Time) and during the initial solidification (Initial Hardness Time).

- Test pulling briefly bonded anchors, which are made to measure strength of AT roof bolting system adopted in concretely conditions. Figure 3 present the scheme of test plucking. This test should be done in the openings with undisturbed working environment (roof) and as close as possible to the working site. Recommended strength for standardized test rapid tied anchors (length 300m) is 120 kN.

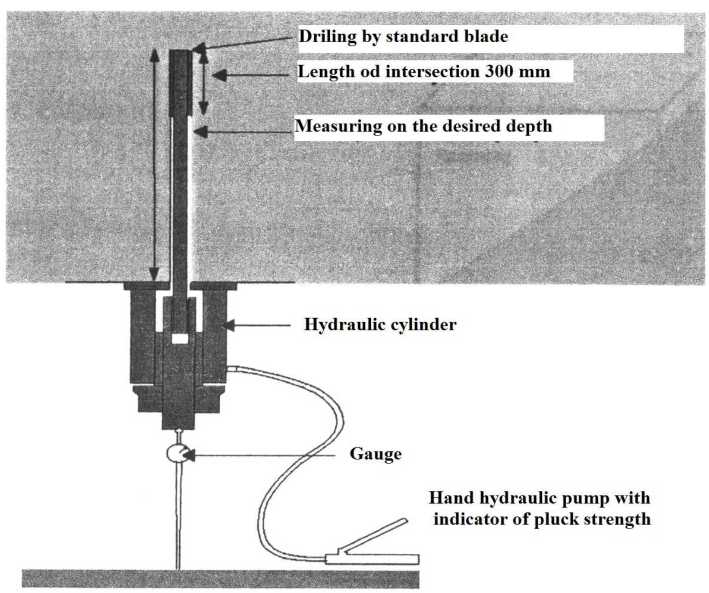


Figure 3 Principled scheme of the test pulling anchors

In test installation the two anchors length 2.4 m fit it, with a fast setting two-compact mixture.

Next, a third activity included the installation of six anchors with five installed in contact with roof, of which three vertically (each of length 1.0 m), at 1-2 feet from the working site or ort (length 1.8 m), to is pulling performed in fresh uncovered roof, where deformation is not spread by depth of rock mass. The all six tests related to short pulling anchor installed, where the length of a connection was 300 m.

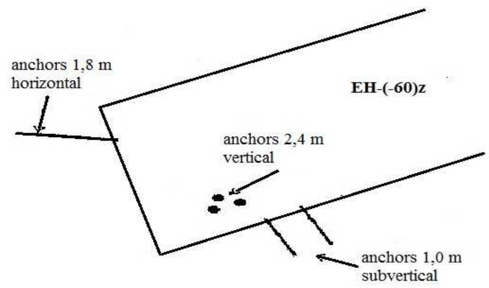


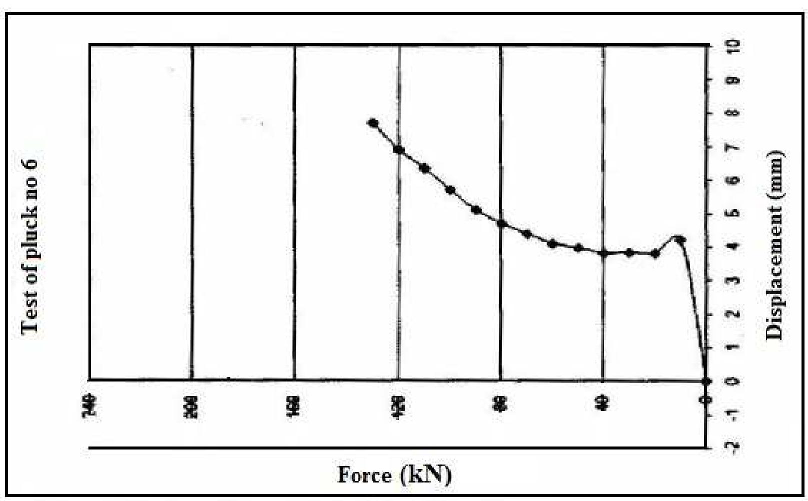
Figure 4 Location of anchors under test of anchor pulling in drift EH- (-60) z

During the implementation of the test pulling came to crushing (breaking) of coal around the hydraulic cylinder because, as already stated, roof of the openings significantly cracked and there is a flat contour, so that the device for pulling test could not be placed in the desired position.

This measurement could not be done at the first five tests pulling anchors, because security and deformation and fracture of coal around the hydraulic cylinder and the occurrence of bending over device for pulling out. For horizontally installed anchor the complete test successfully done: pull-out force and stiffness of connection.

Pull-out force of 200 kN is measured at uprooting of three anchor 2.4 m long, while at uprooting the two anchors length 1.0 value of this force was 210 kN.

Measured displacement depending on the force is shown in Figure 5. Pull-out force (yielding) relation - anchor - mixture-coal in this case is slightly smaller than the anchors that are installed vertically and subvertical, which can be explained by a smaller cleaning borehole drilling and backwardness of fines rock.



Slika 5 Displacement of anchor depending of forces, pluck test

The plucking tests were carried at different depths, in order to evaluate the effect of blasting, or cracking and delamination of seam, on relation - anchor – mixture-rock. It can be concluded that the results obtained by plucking of vertical and the subvertical anchors, length 2.4 and 1.0 m, are in correlation, while the connection of horizontal anchors gave way at a load of 90 KN, which is probably due to residual fine rock materials in the borehole.

Table 2 Summary results of plucking of rapid anchors

No:	Lenght	Place	Measured force (kN)	Comment
1	2.4 m	Vertical	> 90	
2	2.4 m	Vertical	> 110	Preasured to 200kN, preserved relation
3	2.4 m	Vertical	> 100	-
4	1.0 m	Subvertical	> 20	Test aborted due to breakage of coal
5	1.0 m	Subvertical	> 140	Loaded to 210kN,
6	1.8 m	Horizontal	90	-

TECHNOLOGY OF AT ROOFBOLTING SYSTEM OF SUPPORT

The results obtained during the first phase of transfer of the supporting technology in underground drift EH- (-60) z by AT roof bolting system of support created a prerequisite for the transfer continuation, or for the implementation of the second phase - System trial supporting.
During the second phase was carried out the systematic incorporation of AT roof bolting system of support. In the beginning is done installing of anchors according to the initial scheme of installation, with the existing method of support (which remains unchanged) and with the monitoring of the effects that achieves the roof bolting system of support. During the development in accordance with the measurement results are made the possible modifications and optimization of the anchor installing schemes.

When based on the results of measurement and monitoring established the scheme of installing anchors with which achieves the successful control of the rock massive, it is possible to make the changes and corrections of the current method of supporting with steel support. This, as well as any other changes, either in the way of installing AT roof bolting system of support, either in the form and amount of support steel installation, it is necessary to confirm the results of the measurement and monitoring of rock mass behavior on the section from 30 to 60 m , with a minimum interval of about two weeks .

During the third phase of the trial of support it is necessary to confirm adopted manner of supporting by the results of measurement and monitoring of rock mass.

The methodology used for the selection of an appropriate solution of support with roof bolting system of support is based on the measurement and monitoring of the certain parameters: "in situ" and that after the start of systematic installation.

The parameters to be measured and monitored are the behavior of the rock mass around underground openings- strain and loading on which the AT anchors exposed. In this way, one can determine the effectiveness of the adopted solutions, but they can make the certain modifications to the results of measurement and monitoring, until not realized the necessary control over the massif.

Current monitoring of massif (current monitoring) is covered by the supporting decision to continuously monitor the effectiveness could be adopted throughout the duration of underground excavation [11]. The possible changes in stratigraphy and the changes of stress around underground openings, which can determine by the devices for measuring and monitoring , can lead to the a situation when you need to change the manner - a solution of support .

This approach is more reliable compared to analytical or empirical approach in which the capacity of support and the massive load calculated in order to reach to the certain assumptions about the rock mass behavior and the effectiveness of the massive support. Here it is necessary to point out that these assumptions can be fault, especially in the deposits with the varying characteristics. That is why the choice of the appropriate test of support solutions with AT roof bolting support based on the measuring and monitoring the behavior of rock mass and so that is the procedure of choice is divided into several steps.

The first step is to test support with existing frame support, with AT anchors implanted under the initial scheme of installation. The characteristics of transferring loads from massive over solidified two component mixture to anchor, both in terms of ability to accept the anchor loads, as well as in terms of assessing of effectiveness, will be determined by installing anchors with measuring tape .
The next step is the analysis of data obtained by monitoring and measurement, as well as information about the tests pulling briefly associated anchors, in order to determine the effectiveness of the decision and, if necessary modified to improve. Any change - a modification is necessary to confirm by the results of measurement and monitoring.

When the specific solutions of AT roof bolting support installation provide the satisfactory results when measuring and monitoring obtained through sonic extensometer and the anchors with the measuring tapes, can be accessed by any change of the ways of support steel supports.

Current monitoring - monitoring of rock mass behavior with massive sonic extensometers and strain gauges of deformation" Tell- Tale " tests of pulling briefly bonded anchors and direct sampling of the top of the activities to be carried out continuously in the underground openings supported by AT roof bolting support in order to monitor its effectiveness, especially in the situations when there is a change of working environment.

THE MEASURING METHODS AND MONITORING OF APPLIED SOLUTIONS OF SUPPORT

During a test of support with AT roof bolting system and the choice of support on the drift EH- (-60)z established the two basic methods of measurement and monitoring, as follows:

- measuring and monitoring of the applied solutions of support, and
- a current measurement and monitoring.

The objective of measurement and monitoring of support solution is applied to confirm the parameters of the solution, and includes the detailed monitoring of rock mass behavior around of excavation as well as measuring of anchor reaction to loading of rock mass. Data of rock mass behavior are read from the massive sonic extensometers, while data on load anchors read by the sonic extensometers and loaded anchors read by the measuring tapes.

The aim of the current measurement and monitoring is to ensure a safe working environment so as to draw attention to the some changes in the rock mass behavior that require the additional roof supports or another support solution.

Monitoring of the stress state and contour of underground opening deformation is important for the system of support with AT, since exceeding of the certain values threaten the anchor stability and requires the appropriate actions (installation of additional AT anchors, installing anchors of steel wire ropes, installing of steel set of support and etc.).

Figure 6 shows the measuring station that is installed into the excavation EH- (-60) z in the part with a circular cross section.

During the installation should be taken that plane which consist the axis of measuring strip at all anchors is perpendicular to the direction of the underground openings.

Installation of these anchors is performed during the normal cycle of supporting with the same equipment that is installed the standard anchors. Reading is done with adequate instrumentation which designed for use in the methane mode, and in addition it is equipped with a memory unit, with collected data. Data analysis is done on the computers with specialized software, with the possibility of graphical interpretation of the axial loads and bending moments of the anchors.

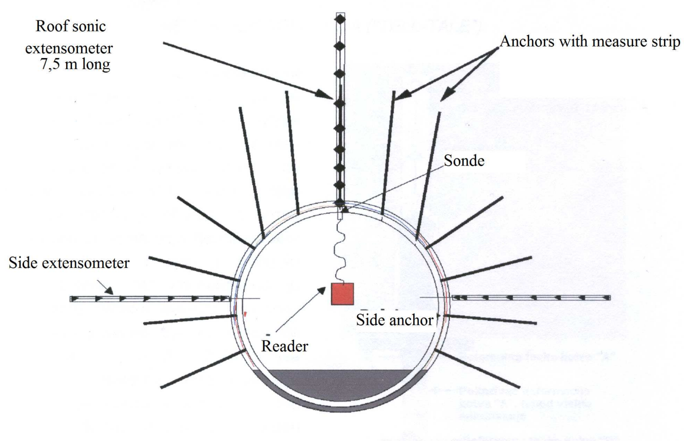


Figure 6 Monitoring station installed in a drift EH- (-60) z

CONCLUSION

Because of importance of the mining facilities in the process of underground exploitation, it is clear that from their functional capacity depends the stability and reliability of production realization of the system as a whole. In addition to stability of underground openings for the manufacturing system is a very important and timely production of the facilities in order to maintain the production continuity by introducing the new excavation units in the process of production.

The some experiences and previous studies of stress in the mine Soko, indicate that the underground openings are exposed to the huge pressures and deformations, and according that it reduces their exploitation endurance. As a consequence of that there is a necessary for their constant maintenance, and very often for the whole rearrangement of system.

Because of these cited problems, the optimal solutions of development and support construction of underground openings have a specific importance as it was on the specific investments.
This paper describes the mining and geological conditions in the coal deposit of Soko mine that directly influence to almost all of the technological processes of exploitation and in particular to the choice of development technology and support of underground openings.

In another chapter are presented the methodology of the existing techniques and development technology and underground openings support at the Soko mine which is mainly used in the previous period of underground exploitation of coal in this mine.

Many years of experience of described development system and support of openings showed a number of disadvantages especially in conditions of the increased underground pressures that have affected the deformation of underground openings with less or great intensity .

The complex mining and geological conditions of coal exploitation, such as in the mine Soko, require the constant research of the new technical solutions of development and supporting of the underground openings.

In fact, in order to exceeding of these problems as well as the proper choice of development technology and underground openings support at the Soko mine achieved a trial introduction of the new technologies, with the primary aim of improving the general condition of underground openings and improvement of development quality, support and thus increase the life of their lifetime as well as creating conditions for a safer and safety work which is certainly a primary objective.

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REFERENCES

[1] Jovanovic, P. (1994). Design and calculation of the horizontal underground openings support. Beograd. Mining and Geology faculty Belgrade.
[2] Magdalinovic, N., Jovanovic, R., Stanujkic, D., Magdalinovic – Kalinovic, M. (2009). Optimization of the mining projects and production. Bor. The Mining Works journal no. 2.
[3] Stjepanovic, M. (2002). The strategic approach of development planning and mineral production in the mining area of Serbia. Bor. The Mining Works Journal no.1.
[4] Miljanovic, J. (2002). The impact factors of coal production realization in the coal mines with underground exploitation of the Republic of Serbia. Bor. The Mining Works no. 1.
[5] Ivkovic, M. (2002). The strategy of coal mines development with underground mining in Serbia in terms of restructuring. Bor. The Mining Works no. 1.
[6] Ignjatovic, M. (2007). Restructuring of the underground coal mines in Serbia. Bor. The Mining Works journal no. 2.
[7] Ivkovic, M., Mladenovic, A. (2001). Modernization of the underground coal mines in order to increase the production and protection of employees. Bor. The Mining Works no. 1.
[8] URP of support testing in underground opening EH-(-60)z in RMU with the combined support, Faculty for Mining and Geology, Belgrade 2010.
[9] Ivkovic, M., Ljubojev, M., Perendic, S. (2001). The exploration of the working conditions for the introduction of mechanized excavation of coal layer I in a "Lubnica" mine. Bor. The Mining Works no. 1
[10] Ljubojev, M., Popovic, R., Ivkovic, M. (2001). Rock mass deformation and subsidence of the ground surface caused by underground exploitation of ore mineral. Bor. The Mining works no. 1.
[11] Ljubojev, M., Popovic, R., Rakic, D. (2006). The basis of mechanical models settings of support interaction with rock mass. Bor The Mining works journal no. 1.