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SEISMIC ACTIVITY IN SURFACE MINE OF ARCHITECTURAL BUILDING STONE AT THE TIME OF BLASTING

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ABSTRACT

Exploitation of architectural - building stone in the form of blocks for further processing as a separate segment of the mining industry,is one of the first human activities that, with the development of human civilization, despite the creation of new materials, not only dying out, but gaining momentum. The exploitation of these stone blocks (marbles, granites, travertines, onyx and others) used as architectural-building stones, explosives and mining methods are applied in a completely different way than in the usual methods of blasting..

Key words: blasting, seismic effects, elastic waves, marble, measurement

1. INTRODUCTION

These blasting methods are used exclusively in combination with the production of limited surfaces of a healthy marble mass by performing side cuts and cutouts with classic machines such as diamond woven saws, diamond chain saw, etc.These limitations are made with the primary task during these mining operations not to damage the surrounding healthy rock masses while breaking down or collapsing the block itself or the crushed mass.The greatest attention is paid to the impact on the surrounding benchess and blocks where the healthy rock mass can not be damaged.

The explosive as a means in mining of the surface pits for the exploitation of stone blocks is generally applied in many technological phases of exploitation and with several different purposes.

Drilling and blasting in the exploitation phase is applied at:

- sprinkling of cracked zones (primarily cracked zones),
- shrinkage of low-quality primary zones,
- making cuts and channels for the formation of a work shaft,
- separation of lamellas from the solid rock masses,
- cutting of dropped lamellas with drilling.

Figure 1. Part of the surface mine for white marble "Sivec", near Prilep

2. GENERAL FOR SEISMIC ACTIVITY AT THE TIME OF BLASTING

The elastic deformations caused by the dynamic effect of the explosion represent an oscillatory process, that is, the seismic effect of the explosion**.**

The formed elastic deformations extend in the form of elastic waves radially from the site of the explosion.With the action of an explosion in the working environment simultaneously, all types of elastic waves are formed, whereby the change in the distance from the blasting site also changes their intensity.The intensity of the seismic waves can be determined by measuring one of the basic dynamic parameters of the moved environment, and this:

oscillation speed (V),

acceleration(a)and movement on the ground (x).

The connection between these parameters is obtained by analytical calculations.

The parameter which is used most often for assessing the seismic intensity is:the speed of seismic oscillations on the moved ground (v).

The maximum speed resultant of ground oscillation (vmax) is obtained as the intensity of vectors with components in the X, Y and Z axis according to formula:

$$V_{max}=\sqrt{V_v^2+V_l^2+V_t^2}\ \text{, (mm/s)}$$

Where are:

- V_v - a vertical component of the oscillation speed of the ground, (mm/s);
- V_l - longitudinal speed component of the ground oscillation, (mm/s);
- V_t - transverse speed component of groundoscillation, (mm/s).

The registration instruments are placed on hard ground, dug into the ground or the rock. They can also be installed in building structures on a concrete base or hardly compacted earthen ground. The installation of the instrument is always directed with the arrival of seismic waves.

2.1. Registering of the vibration

At points of observation, the waves formed as a consequence of the blasting effect arrive almost simultaneously, causing the movement of the soil particles in different directions. The material particles of the ground oscillate in space and time along very complex paths.

The vibrations are registered in three directions, through the:

1. A horizontal component, perpendicular to the direction of wave propagation, the so-called transverse component, V_m;
2. Horizontal component, oscillation in the direction of wave propagation, so-called. longitudinal component, V_l;
3. A vertical component, V_v.

As the most influential and appropriate parameter for the evaluation of the seismic action during blasting, usually is taken the speed oscillation of the ground.

It is considered that it best correlates and describes the danger of vibrations and damage that can be caused, so all standards and criteria for protection against vibrations are based on the speed oscillation of the ground. By reading from the instrument, we can calculate the maximum oscillation speed (Vmax) and the actual (real) maximum oscillation speed (Vstv).
The real maximum oscillation speed is obtained by reading the amplitudes from the recorded velocity in the same time interval for all three components, and then calculating the resulting real speed using the same formula.By using the maximum oscillation speed (Vmax) to evaluate the seismic action from the blasting, the results are fairly reliable, since the maximum oscillation speed is always greater than the actual, and the real one is that which acts on the object.

2.2. Criteria for assessment of seismic action during blasting

Regulations are regulated in several countries that regulate the level of vibrations caused by blasting that can load objects depending on their significance, condition and dynamic resistance.Such regulations have not yet been adopted in our country in order to solve such problems, we are using regulations and norms from abroad, that is, usually according to Russian, German and American standards.

The intensity of the quake-caused from blasting is sometimes estimated through a scale used in seismology, most often with the Merkali-Kankani-Siberge scale, this scale is known as the MCS scale.Although there are differences between quakes from blasting and quakes from earthquakes, the differences are significant especially during the duration of the quakes, the oscillation period, etc.In determining the permissible deformations for objects that are located on a certain type of rock mass, the deformation characteristics and physical and mechanical characteristics of the corresponding rocky massif are of great importance.

It can be concluded that the vibration, if it is of high intensity, causes such pressure in the rock material, to deformations cross the boundary of elasticity and the appearance of additional mechanical deformations, with these deformations, especially in the marble mass, there are cracks and lasses that make the production of commercial blocks of good quality difficult. For the stability of an appropriate object or rock mass, take into account the calculated permissible deformation, in which the elastic behavior of the rocks must not pass the value of 0,0002-0,0005.

Table 1. Description of the appear in the rock massif

Description of rock mass deformations caused by seismic waves	Speed of oscillations, cm/s
There are no deformations	<20
Occurrence of insignificant development of cracks from previous blasting, a mystic fall of individual pieces of slopes from previous damages	20-50
Intensive development of permanent cracks, individual crumbling of smaller pieces of rocks, occurrence of rocks in tectonically weak rocks and collapse of the slopes after tectonic deformations	50-100
Development of tectonic cracks and collapse of pieces with dimensions 0,5x0,5x0,5m	100-150
Collapse from the sides and roof parts of the underground rooms, after tectonic cracks, formation of new cracks, demolition of protective pillars and parts of the bench	150-300
Fully damaging the sides of the slopes on larger sides 1x1x1m and filling the underground rooms to half the height and breaking down the slopes from the solid rocks	300-400
Full decay of the rocky massif, the collapse of large blocks larger than 1x1x1m and the burial of the underground rooms more than half of the entire height	>400

Table 2: Allowed oscillation speeds by rock type

Characteristics of the rocky massif	Coef. of hardness, f	Velocity of long wave, C_p(km/s)	Allowed oscillation rate of the object by category, cm/s			
			I	II	III	IV
Unbound alluvium	0,5-1	1-2	4,08	8,2	12,2	20,4
Strongly cracked clay with clay and high porosity	1-3	2-3	6,80	13,6	20,3	34,0
Layered rocks meaningfully cracked	3-5	3-4	9,50	19,0	28,4	47,5
Significantly homogeneous rocks with individual cracks and cavities	5-9	4-5	12,2	24,4	36,7	60,0
Faint cracked and monolithic rocks	9-14	5-6	14,9	29,8	44,6	74,5
Very solid and monolithic rocks	14-20	6-7	17,8	35,6	53,3	89,0

3. CONCLUSION

Miner works have a detrimental effect on the surrounding benches in the mines for architectural-building stone, and the most damaging influence are the seismic waves that are unavoidable and extend and activate the already existing cracks and create new ones, and in these mines, the best quality of the commercial block its set on.

However, the blasting cannot be excluded as one of the most important primary mining operations.

So we should try to find ways to minimize these harmful effects.Therefore, only those masses that are already damaged, ie that do not have a good quality for sale, are usually mined and are contoured so as not to transfer the waves from the blasting of a healthy marble mass.

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SAFETY MEAUSERS AT COAL EXTRACTION IN VELENJE COAL MINE IN ORDER TO PREVENT THE EFFECTS OF SUDDEN INRUSHES AND OUTBREAKS OF COAL GASES

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ABSTRACT

Velenje Coal Mine developed, with respect to the natural forces of fracturing and crushing of the coal layer, one of the most effective longwall top coal caving mining method for thick coal layers. "Velenje mining method" with collapsing of overburden strata in excavated area is developed since 1952. The process of controlled caving by pouring crushed coal in the front of flexible canopies and on the armored face conveyor allows very high extraction capacity with provided safety. This procedure, however, requires a good knowledge of caving processes "in situ", advanced excavation equipment and in particular, knowledge and experienced miners. Successful control of caving and continuous collapsing of excavated area is one of the key stages of the technological process for the efficient and above all safe extraction of coal. From the safety point of view, this means in particular the prevention of sudden inrush of coal gases in the work area of coalface as consequence of sudden collapse of overburden strata in the extracted area. Also, due to the impact of mining especially when the coalface is crossing the coal layer Faults or old works, the potential danger exists of an outbreak of coal gases in the area of coalface and gateways. This paper presents measures for safe excavation that are integrated in the Velenje Coal Mine's "Prevention and protection plan" in the case of potential risks and at the occurrence of inrush or outbreak of coal gases in the area of coal face and gateways.

Key words: Velenje mining method, inrush and outburst of coal mine gases, prevention and protection plan

1. INTRODUCTION

Velenje Coal Mine is mining one of the thickest lignite layer known in the world, with a maximum thickness of more than 160 m. Velenje Coal Mine developed, with respect to the natural forces of fracturing and crushing of the coal layer, one of the most effective longwall top coal caving mining method for thick coal layers. The "Velenje mining method" with collapsing of overburden strata in excavated area is developing since 1952. In the present system, the extraction from top to bottom of a thick lignite layer is delimitated on pillars (horizontal delimitation) and horizons (vertical delimitation). In Velenje the longwall extraction principe was developed in to major variants: horizontal concentration and vertical concentration. Whit introduction of "safe extraction criteria" under aquifer layers, which allow continuous change in the height of the extraction in dependence on the thickness of the insulation layer above the coal layer, the pressure of the water in the aquifer layer above and the depth of the longwall face, the difference between the horizontal and the vertical concentration is lost. We are only talking about the longwall method with increased or variable extraction height [3].

The process of controlled caving by pouring crushed coal in the front of flexible canopies and on the armored face conveyor allows very high extraction capacity with provided safety. This procedure, however, requires a good knowledge of caving processes "in situ", advanced excavation equipment and in particular, knowledge and experienced miners. Successful control of caving and continuous collapsing of excavated area is one of the key stages of the technological process for the efficient and above all safe extraction of coal.

Velenje Coal Mine developed and upgraded longwall equipment to a large extent, themselves. Manufacturers of equipment like to cooperate, because of our experience and continuous development. We also produce certified hydraulic supports and in the greater part the armored face conveyor (AFC) and beam stage loader (BSL). The current standard set of longwall equipment for the lengths up to a ca 220 m consists of:

- Hydraulic support with a width of 1.75 m and a height of up to 4.7 m. The first four and the last three, i.e. drive sections, are located at crossroads with extended canopy to cover the front and rear drives of AFC. Working pressure is 310 bar. Section control is PMC-R and PM4 type.
- AFC JOY: conveyor: length of pan 1.75 m, width 0.9 m, chain 2 x 38 mm x 126 mm, drive 2 x 400 kW VSD motors, Q = max 1250 t/h, v = 1 m/s, planetary gearbox L 700 BP).
- Shearer Eickhoff SL 300: weight 50 t, total power of 845 kW, 3300 V).
- BSL JOY whit crusher (160 kW) and hydraulic breaker: (1 x 400 kW VSD motor, Q = max 1250 t/h, v = 1.08 m/s, lenght = 37.5 m).

In parallel with technological advance and increasing productivity, focus is mostly on safe coal extraction in terms of prevention and timely action in the event of a hazard. Identified potential hazards that accompany the coal mining process in Velenje Coal Mine and threaten the employees and the mine are: outbursts, exhausts, exhalations and inrushes of dangerous coal gasses; outbursts of water, sludge or mud; mine fire; methane explosion; coal dust explosion; explosion of explosives; power and telephony failure; rock bursts. Prevention and protection measures are integrated into the "Prevention and Protection Plan" of Velenje Coal Mine.

For many years in Velenje Coal Mine, we are working on measures that would eliminate as much as possible the dangers associated with sudden outbursts and inrushes of dangerous coal gases, methane (CH_4) and carbon dioxide (CO_2). The inrush of coal gases occurs most often at the technological process of coal extraction at the coal face. This means the sudden inrush of coal gases in the work area of coal face as consequence of sudden collapse of overburden strata in the extracted area (goaf). The gases are accumulating in the unventilated goaf area due gases exhalations from the coal. Also, due to the impact of mining especially when the coal face is crossing the coal layer faults or old works, the potential danger exists of an outbreak of coal gases in the area of coal face and gateways.

In case of outbursts or inrushes the coal gases permissible concentration limits can be exceeded up to several times and pose a great threat to the life of the workers present longwall area. An example of a sudden increase in CO_2 concentration is shown in Figure 1.

Figure 1: An example of a sudden increase in the CO_2 concentration at the face [4].

2. DEFENSE AGAINST THE THREAT OF INRUSHES AND OUTBURSTS OF DANEGROUS COAL GASES

Among the more successful prevention measures on CMV against the risk of inrushes and outbursts of CO_2 and CH_4 at the coal extraction, which are applied:

- regularly drilling in potentially endangered areas,
- excavation strictly after a technological cycle,
- consistently closing the excavated area (goaf area),
- consistently closing the old works after completed coal extraction,
- consistent maintenance of longwall and safety equipment,
- proper ventilation of longwall area,
- intensive control of gases concentrations in endangered areas by the mining supervisor of longwall face,
- continuous (real-time) monitoring of gases concentrations.

In the event of inrushes or outbursts of CO_2 and CH_4 (retreat from an endangered area), the protection measures are:

- Use of self-rescuing insulating apparatuses (every employee in the mine carries one on the belt),
- use of respirators that are directly connected to the compressed air network,
- alarming the inrushes or outbursts of CO_2 and CH_4 with the flash light system on the longwall and development faces and in return airways,
- auxiliary ventilation on the longwall face,
- automatic shutdown of electrical devices at increased methane concentration above the permitted limit (ATEX).

3. RESPIRATORS

In order to achieve greater safety of people in mining operations, in 2003 we started using respirators.

The phenomenon of inrushes or outbursts of CO_2 and CH_4 on the worksite the occurrence of outbursts or outbreaks of dangerous coal gases is accompanied by an increased concentration of dangerous coal gases. This may also result in a change in the direction of the airflow and the possible temporary suspension of ventilation. The normal airflow direction and speed can be restored from a few seconds to a few minutes. However, the CO_2 and CH_4 concentrations can be lowered even within a few hours. With this phenomenon, workers have to retreat to a safe area as defined in the "Prevention and Protection Plan". At the event miners first approach and use the respirators whit inrush of fresh air, which allows miners to month the self-rescuing insulating apparatuses in a calm manner and retreat to a safe area. By the term respirator we mean a mechanical device that is connected to the compressed air network with a flexible tube and is installed on accessible places at the height of the head (Figure 2). In this way, we provide an independent source of fresh air from a compromised atmosphere.

The respirators are supplied from the compressor station on the surface. The compressor station is composed of six screw compressors manufactured by KAESER with a total capacity Q = 120 m^3/min, at a pressure of 7 bar. Compressors are commissioned in terms of air consumption. The compressor incorporation is automatic depending on the pressure in the pressure vessel. The mine network is connected with pipeline DN 200 through the shaft. The main mine pipelines are DN 125 and DN 100. Pipelines to the worksites are DN 80 [1]. Before connecting the respirators, a standby group is installed, where air condensate and oil droplets are eliminated. Pressure in the compressed air network is from 5 to 7 bar.

In the respirators are installed flow regulators in order to avoid excessive discharge. The respirator is designed so that the outlet air stream in the breathing mask creates an overpressure. Thus, the user is constantly using the uncontaminated air.

In case of inrushes or outbursts of hazardous gases, the supervisor, group leader or supervisor in the main control room of CMV issues a command "apparatus, retreat, gas" [2]. The miners keep their breath, they approach the respirators, open the airflow controller, and wait for a second to two to exhale settled dust and condensate in the air bag. They then approach the cheek and begin to breathe normally. With normal breathing, the self-rescuing insulating apparatuses can be installed in peace and without panic. This is followed by the retreat to a safe area as defined in the "Prevention and Protection Plan".

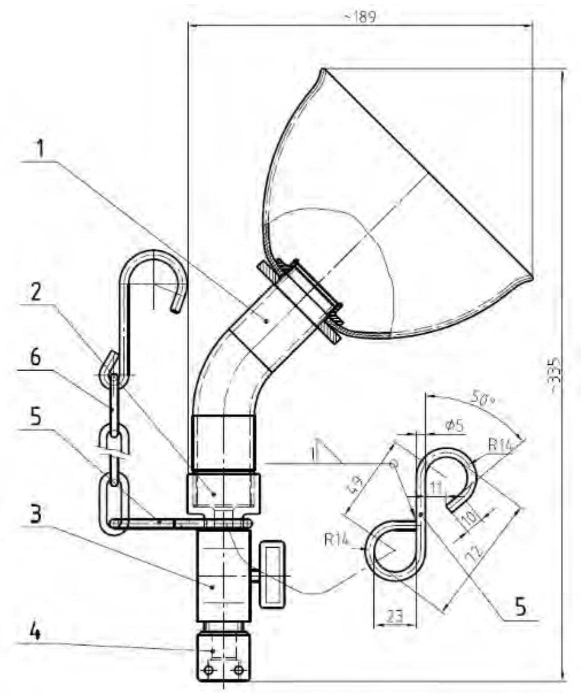

Figure 2: Single respirator.

Legend:
1. Single respirator
2. Airflow regulator
3. Ball valve 1/2″′
4. Connection of flexible tube on network
5. Hanger of respirator
6. Chain with hook

Locations of respirators

On the long wall faces, a single respirator is installed on each section of the hydraulic support. In the entering airway before the entering the face, four triplets of respirators are installed. In the return airway just after the face, three triplets of respirators are installed. The triplets of respirators are also located along the whole length of entry and return airways at every 18 m.

At the development faces, the triplets of respirators are installed:
- From the face to a distance of 10 m, two triplets of respirators.
- Followed by, at a distance of three times 6 m, 3 times one triplet of respirators and then
- along whole length of roadway, on triplet of respirators on each 18 m.

At drilling worksites, an additional set of triple respirators is installed on each side of the drill set. In the main exit roadway (main return airways), the triplets of respirators (Figure 3) are positioned at each 24 m.

Figure 3: Example of installation of the triplets of respirators in the side of the roadway.

4. FLASHLIGHTS ALARM SYSTEM FOR INRUSHES AND OUTBURSTS OF COAL GASES

Although we have a very well-developed monitoring system for stationary continuous sensors and mobile measurements of dangerous coal gases, information on the occurrence of inrushes and outbursts of CO_2 and CH_4 can be identified too late for timely action.

In order to inform as quickly as possible the entire endangered area, in 2005, we developed the first system for alarming inrushes and outbursts of CO_2 and CH_4 with a flashlights system that draws attention to the danger with an acoustic and light signal.

First, we developed an alarm system with the TX 6831 type flashlights manufactured by Trolex based on a parallel dual system. In recent years, we have developed an even more efficient system with Woelke AGS 01 flash lamps, which is based on two-stage alarm level in one flash lamp [9].

Configuration of flashlights system (Woelke, type AGS 01)

The Woelke flashlights, type AGS 01, has two alarm levels, each level being controlled via a separate input. The first alarm level (exceeded by the concentration of the monitoring gases above 1.5%) activates the red light signal with a flashing interval of 2 s, the second alarm level (exceeded concentration of accompaniment gases exceeding 3%) and triggers a light signal of the same color, but with a flashing interval 1 s, but also a continuous acoustic signal.

The second level of alarm is set so high that it can that we can undoubtedly separate the exhalation of coal gases due to technological process and actual inrushes and outbursts of coal gases that pose a life threat to the present miners. In the event of activating the 2nd level of alarm, the present miners know immediately that this is a dangerous event and they can take action without any prior warning from the supervisors in the Velenje Coal Mine. Action time is vital.

In the event that both levels are activated at the same time, the second level is preferred. In the terminal box, the flashlights also have two keys. The first key allows turning off the active alarm, and with the second key, anybody can check the operation of the device. If it works properly, both acoustic and light alarms are activated when pressed. For the transmission of a light signal (first level) and also an alarm (second level), the flashlights have built-in 10 super bright LEDs, which illuminate in all directions. For the transmission of an acoustic alarm, the flash has a built-in tone generator with a variable frequency from 2400 Hz to 2850 Hz.

Due to the simple design and operation of the two-level system, the employees are focused on lighting and audio signals and there is no need for continuous monitoring of stationary gas sensor. The Woelke AGS 01 configuration is implemented in accordance with the ATEX directive and is in line with the explosion protection Ex I (M1) M2 SYST EEx ib / ia I and is shown in Figure 4.

Legend:
1 Self-powered power supply type USV 4.2,
2 Signal-alarm device (flash lamp) AVS 4.1
3 gas sensor MONIMET type GMM 01.04

Figure 4: Flash lamp system configuration [11,12].

The flashlights are located on the longwall face, return airways of the face and main return airways. The locations are determined in the way that from each part of endangered are can be detected at least one flashlight. Maximum distance between flashlights is 150 m. The system allows separate activation of each flashlight with specific gas sensor in the area, which allows customized automation on a case-by-case basis [10].

5. SAFETY AND TECHNOLOGICAL INFORMATION SYSTEM AND REAL-TIME "PREVENTION AND PROTECTION PLAN"

Safety and technology information system (STIS) was built in 1990, which is considered as the year when the first microprocessor control device was installed in the Velenje Coal Mine . The information system covers the needs of the entire cave. Data logging is at the level of sensors or meters that measure different analogue and digital parameters. Most of these parameters are of a safety character, and some of them are for a technological monitoring and control. The measured signals are sent to the processing stations, which process the signals and display them on the LCD displays, while at the same time the information is also transferred the surface, where they are further processed in the information centre [5].

The main purpose of transferring data to the surface is to carry out a centralized inspection of all the parameters relevant for solving the crisis situations in the mine. The data are from the processing stations in the mine to the communication computers, which further communicate with the main control computer in the information centre. The data are displayed in real time and archived for a longer period of time. Data are processed and displayed in various forms, such as: alarms, events, diagrams of current and historical values, process diagrams, map of the mine with the displayed sensors locations and real-time values of individual parameters [5,6,7,8].

The most important goal of using STIS data is to maintain the required level of safety in the mine and extraction process. The STIS data are the basis for informing employees about specialties in the mine and of detected dangers and endangered areas because of that danger. After such detection is immediately organizing their retreats from endangered areas to a safe area in the mine or directly to the surface. For a faster, timely and effective action in accordance with the "Prevention and Protection Plan" based on real-time CH_4, CO_2 and CO values and ventilation mine maps. A real-time display (example on Figure 5) based on processed increased gases values enables the display and alarming of endangered areas. Based on two-level arming system with flashlights is possible to detect and confirm separately gases exhalation and inrushes or outbursts of CH_4, CO_2 with display of endangered area. Also based on carbon monoxide (CO) sensors a display of potentially hazardous areas by a mine fire is possible [6,8].

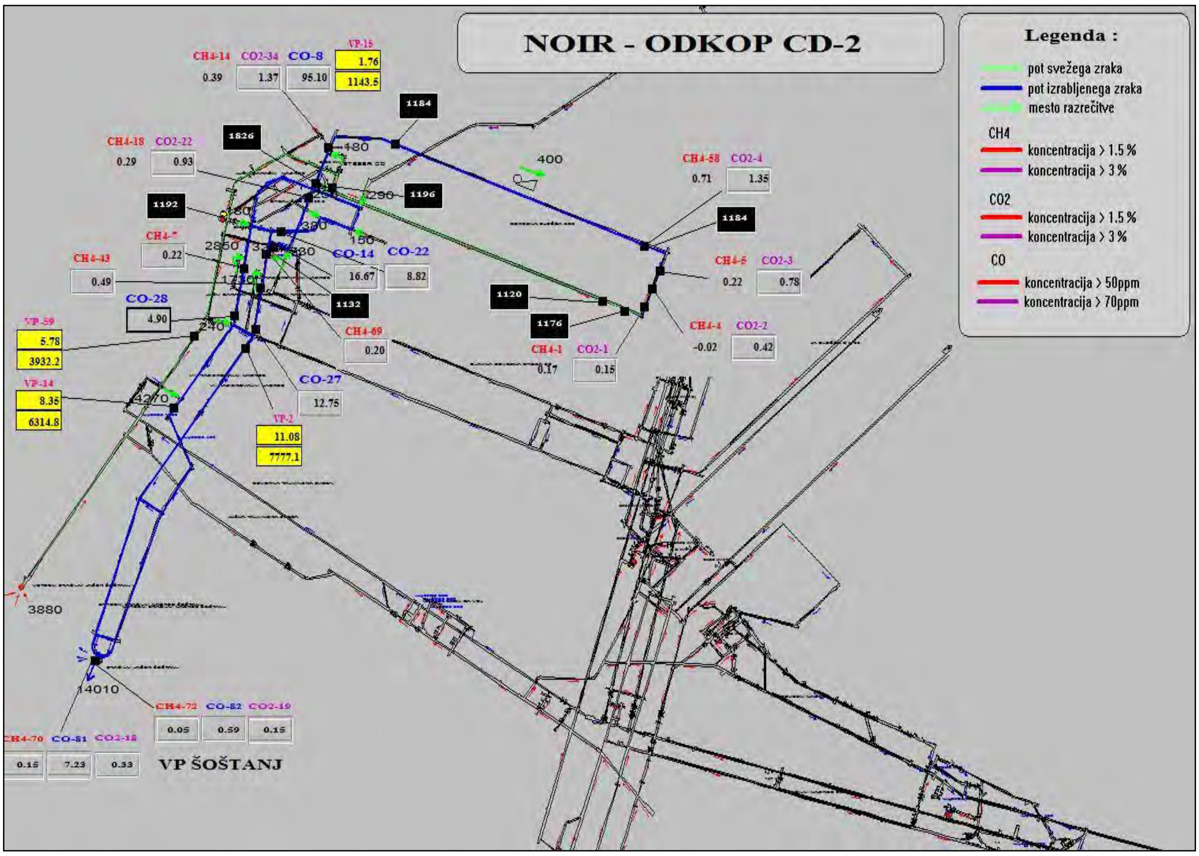

Figure 5: Display of real-time Prevention and Protection Plan [11, 12].

CONCLUSION

Ensuring safety and health of miners is a main priority in Velenje Coal Mine . Sudden inrushes and outbursts of methane and carbon dioxide at coal extraction represent extremely hazardous events that cannot be foreseen or predicted in advance.

An important role in ensuring occupational safety and health at sudden inrushes and outbursts is additional measure, the implementation and use of the respirators in Velenje Coal Mine . These allow the safe breathing of fresh air in the event of sudden inrushes and outbursts of dangerous coal gases and a peaceful and without panic mounting of an self-rescuing insulating apparatus. This is essential for safe retreat in to the safe area as defined in the Prevention and Protection Plan. The supply of the air is directly from the compressed air network which is supplied from the compressor station on the surface.

In order to protect the miners effectively, timely information on the increase of coal gases concentration and the alarming of danger in case of inrushes an outbursts is decisive and vital. Successful detection, reporting and alarming of these dangerous phenomena with the described systems gives timely possibilities for implementing the necessary technical and security measures.

In Velenje Coal Mine, a two-level system with flashlights for the alarming of dangerous concentrations of methane in carbon dioxide allows the immediate detection of increased concentrations at inrushes and outbursts at the coal extraction process.

Real-time data acquisition via sensors and meters are processed through a safety and technology information system that enables the preparation of graphical bases for displaying and remote monitoring of technological processes and the most important, real-time display of endangered areas, which enable immediate action in the coal mine in accordance with the procedures defined in the Prevention and Protection Plan of Velenje Coal Mine .

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