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C O N T E N S

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Marko Babovic*, Radivoje Milanovic*, Branko Jevtic*

ENERGY PROJECT " STAVALJ"

Abstract:

In 2013, the Ministry of Mining and Energy, in cooperation with the Electric Power Industry of Serbia initiated the Stavalj Project development examining mine development supplying coal to the future 350MW thermal power plant, building of the power plant in question and connection to the Serbian power grid.

A prerequisite for analysing project feasibility is to define the technical elements of this complex mining and thermal power system. For this reason, essential input for the entire project is raw material consideration, i.e. a realistic analysis of the raw material coming from the Sjenica (Stavalj) coal basin and its interaction with the future large-scale coal mining.

One of the basic sustainable development concepts of the entire Serbian power system, i.e. Electric Power Industry of Serbia is the provision of the required annual coal production from mines to cover the needs of the installed thermal power capacities.

As a result, such a need is reflected on the Stavalj Project simultaneously representing a crucial assumption for the entire Project.

This paper presents an in depth analysis of the Stavalj Energy Project geological and mining aspects.

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1. INTRODUCTION

Potential Stavalj thermal power plant development has so far been repeatedly examined and studied.

This project was first mentioned in a document dating back to 2004, entitled *Strategic Consolidation of the Public Enterprise for Underground Coal Mining* drafted by the consulting firm Faktis and funded by the World Bank.

Following the request by the Ministry of Mining and Energy, in 2006, a study was prepared investigating the Stavalj mine development as a potential coal supplier of the power plant. This document was prepared by the Czech company *Vystavba dolu Ostrava, s.r.o.* and financed by the Czech Government in the form of a development assistance. In 2007, the European Agency for Reconstruction supported the development of the *Stavalj Mine and Power Plant Pre-feasibility Study* drafted by the German consulting company DMT and the Faculty of Mining and Geology, Belgrade.

The latest initiative in this direction by the Ministry of Mining and Energy was launched in 2013 when a Czech company *Alta* was commissioned, together with representatives of public enterprises EPS, EMS and PEU Resavica, singling out the need to produce a technical document integrating the analysis of the mine, thermal power plant and a power grid connection as a starting point for the development of a Pre-feasibility Study with the General Design and other necessary documentation.

This paper shows the basic assumptions of the Stavalj Project arising from the present technical document.

2. GEOGRAPHICAL AND GEOLOGICAL CHARACTERISTICS OF THE SJENICA (STAVALJ) COAL BASIN

Sjenica coal basin is located in the far southwest of Serbia, some 12km away from Sjenica and 42km from Novi Pazar. Territorially, it belongs to the Sjenica Municipality. Transport links are unfavourable involving with only roads. The basin is connected by an asphalt road Sjenica - Novi Pazar - Raska with the Ibarska Magistrala motorway, or by Sjenica - Nova Varos with the Adriatic Motorway.

Sjenica coal basin consists of three coal deposits, geographically divided into: east field, central field and west field. Each of these fields, in fact, represents a coal deposit within the basin. The most important deposit, both spatially and geologically is the West Field. It is characterised by a low exploration level. The most explored part of this field is its northern area, where explorations were carried out along a regular borehole grid, at a distance of 125m x 125m identifying the geological reserves of B category. The remaining part of the West Field was investigated along a less dense borehole grid at the distance of 250m x 250 m thus evidencing the geological reserves belonging to C_1 category. Based on the above explorations, it may be assumed that some 35% of the West Field area contains geological reserves of B category, while 65% contains the C_1 category reserves.

The Central Field is the smallest deposit of this basin. First coal mining operations commenced in this field by opening a transport and ventilation incline. Its exploration level is by far the best (125m x 125m). However, practice has demonstrated that despite the dense borehole grid, the tectonic structure of the deposit has not clearly been defined, i.e. that the mining operations within the explored geological blocks have entered into completely unclear coal-bearing zones, tectonically disturbed and containing high water levels. For these reasons, mining operations within the deposit have frequently been suspended as entirely technically and economically unjustified. This complex structural-tectonic layout directly influenced the coal production volume, amounting to an average of 60,000 t to 80,000 t per year.

East Field, the second largest field, was developed from an existing pit. Difficult coal mining conditions in the Central Field have led to the development of the East Field from the existing capital rooms, where coal is mined out today. This field is subject to intense additional investigations, because most of its area has been investigated along a sparse borehole grid, at the distance of 250m x 250m, i.e. it contains geological reserves of C_1 category. Deposit location within the Sjenica coal basin is shown in the following figure.

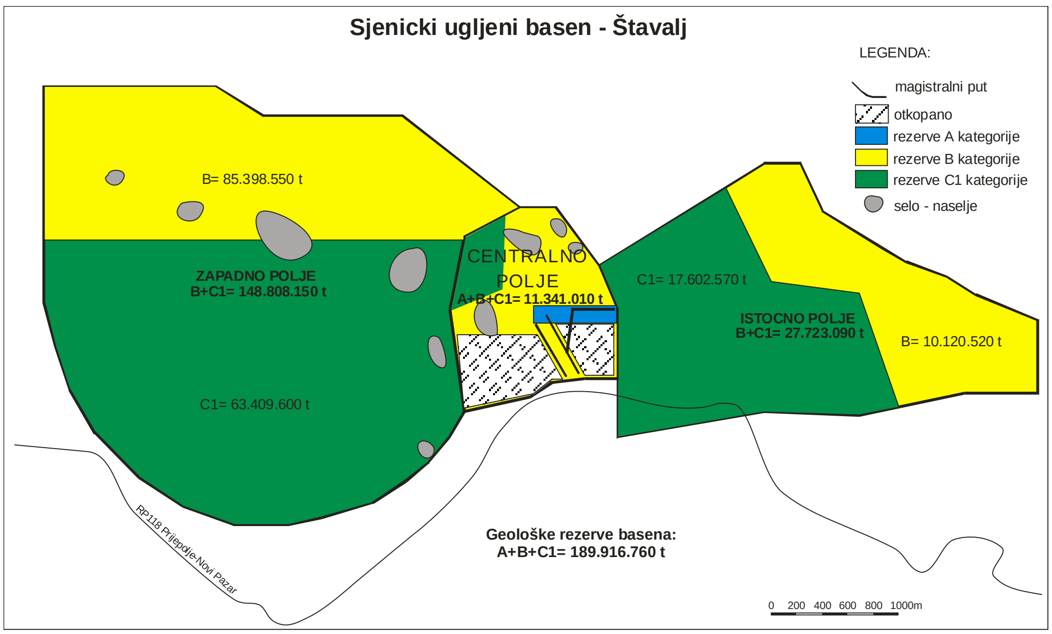

Figure 1 Stavalj coal basin layout including geological coal reserves

The basin also contains one more coal seam with a thickness of 3 - 27m. However, the average coal thickness within the basin is 11 - 13m. The average thickness of the clean coal is some 10m. Immediate floor and roof of the coal seam consist of a solid and consolidated marl.

The entire basin contains large fault structures ranging from 20m to 40m. The basic characteristic of its structural layout is block stratification present in the entire basin and each of the fields. West Field investigated as part of large-scale coal production efforts is similar to other fields of this basin. The size and spatial position of the tectonic blocks in the West Field have not been defined, which is essential for coal production planning. Tectonic blocks are of irregular geometric shapes. Analysis of the structural and tectonic layout has indicated that the West Field tectonic blocks are represented by irregular tetrahedrons and prisms whose average side length is some 1,000m, less frequently 1,500m. Tectonic blocks sides' width is in the range of 300m to 1,000m. Tectonic blocks are also geological blocks clearly separated by fault surfaces. In most cases, mutual boundaries of tectonic blocks are clear and sharp, with a cut fault plane, lowering or raising the adjacent block. There are rare cases when the boundary between two tectonic blocks is a mylonite zone, ranging up to tens of meters in size and containing fully altered physical-mechanical parameters of the working environment. Vertical distance between the tectonic blocks is in the range from 20m to 50m, and in some instances 70m.

Such intense tectonic activity in the Sjenica coal basin deposits, even in the most attractive deposit – West Field, resulted in the formation of separate mining fields from each of the tectonic or geological blocks. Therefore, every mining activity during the coal mining phase should be planned and carried out for each of the tectonic blocks separately. For this reason, at the later stage it is essential when deciding the mining method and mining machinery to have a precise and correct definition of tectonic blocks as a working environment. This primarily includes block geometry, reserves and pertaining coal quality, together with the geotechnical and hydrogeological characteristics of the tectonic block.

As a rule, faults and fault zones in this basin are potential areas of the increased groundwater inflows. Constant groundwater inflow into mine openings ranges from 80l/s to 100l/s, while in the fault zones it may be twice or trice as higher. This further requires serious preparation and protection against inflows and potential penetration of groundwater into mining areas. This complex structural and tectonic layout of the West Field calls for strong caution in planning investment activities and their careful execution in terms of procurement and installation of the necessary mining equipment and other machinery.

Distinctive geological profile of the Central Field is presented in the figure below (№ 2) showing the structural - tectonic layout, which may be representative of the entire Stavalj basin, i.e. other two fields of this basin.

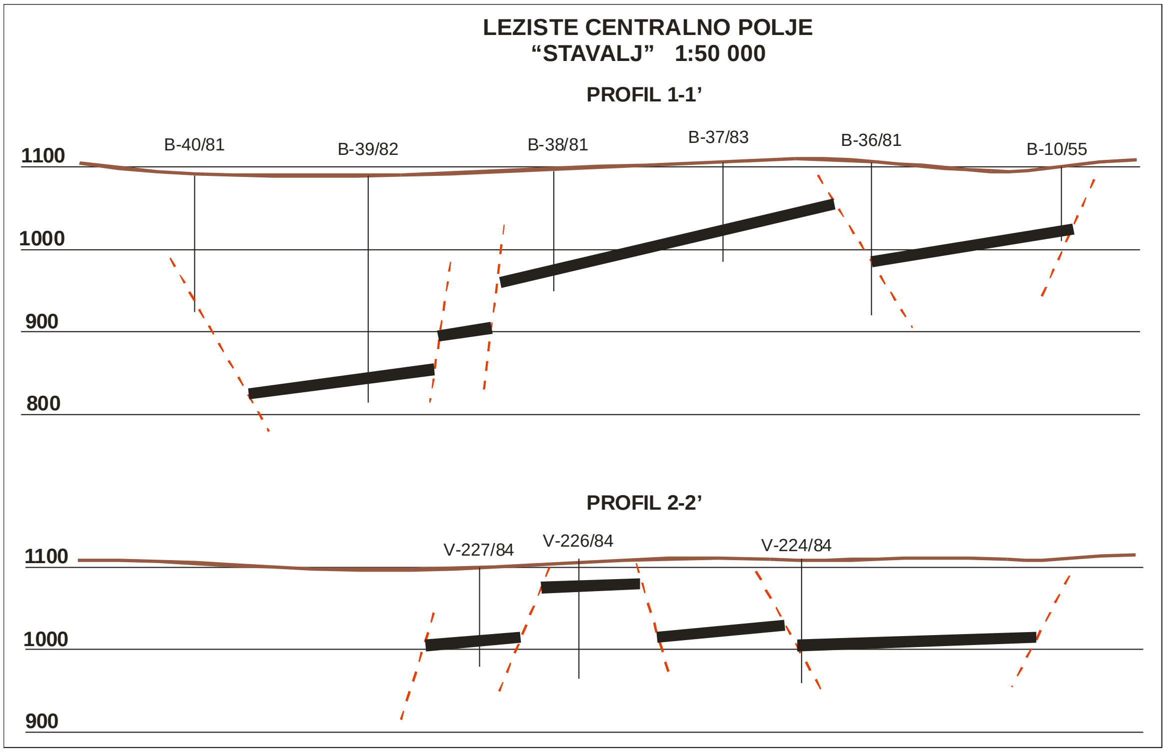

Figure 2 Structural profile of the Stavalj basin coal deposit

3. GEOLOGICAL AND MINEABLE RESERVES IN THE WEST FIELD - SJENICA BASIN

Of the basin's total geological coal reserves, the largest reserves are located in the West Field. West Field was explored in more detail in its northern part, where the geological reserves of B category were identified. The remaining, larger part of the field was investigated at the level of basic geological surveys, when geological reserves of C_1 category were discovered. Table 1 shows the geological reserves of the West Field.

Table 1 West Field geological reserves (internal calculation)

Category	B	C1	Total
Geological reserves (t)	85,399,000	63,400,000	148,799,000

Large amount of blocks within the West Field also conditions the amount of mineable coal reserves in this area. Calculation of mineable reserves should be executed for each tectonic/geological block separately, and only for those geological blocks where large-scale, mechanized coal mining is possible.

In studies carried out so far examining the mineability of West Field, mineable coal reserves were calculated for those tectonic/geological blocks where in the authors' opinion it made sense to form a mechanized, frontal excavation of coal. The 2006 analysis predicted possible coal mining in 21 geological blocks of the West Field.

This mineable coal reserves calculation is shown in the table below.

Table 2 Mineable reserves calculation (calculation origin?)

Stanje - April 2006 | Kategorija rezervi C1 (METODOM YURC,

br. bloka	sorta rez.	povezivost	rezervi	exploat.	korišćenje	sorta rez.	povezivost	rezervi	exploat.	korišćenje
			kt	kt	%			kt	kt	%
1	N	Vol+Váz	2 141	0	0.0					0.0
2	B+N	Vol+Váz	15 132	7 884	52.1	B	Vol	12 204	7 884	64.6
3	B+N	Vol	3 352	0	0.0					0.0
4	B+N	Vol+Váz	17 745	4 076	23.0	B	Vol	10 340	4 076	39.4
5	B+N	Vol+Váz	2 581	764	29.6	B	Vol	1 809	764	42.2
6	B+N	Vol+Váz	3 706	1 446	39.0	B	Vol	3 246	1 446	44.5
7	B	Vol	3 999	0	0.0					0.0
8	B+N	Vol+Váz	8 885	3 425	38.6	B	Vol	7 779	3 425	44.0
9	B+N	Vol+Váz	15 753	6 561	41.6	B	Vol	11 132	6 561	58.9
10	B+N	Vol+Váz	9 581	4 969	51.9	B	Vol	7 639	4 969	65.0
11	B+N	Vol+Váz	5 215	0	0.0					0.0
12	B+N	Vol+Váz	12 153	4 912	40.4	B	Vol	7 525	4 912	65.3
13	B+N	Vol+Váz	31 722	18 666	58.8	B	Vol	28 012	18 665	66.6
14	N	Váz	177	0	0.0					0.0
15	B+N	Vol+Váz	1 565	0	0.0					0.0
16	B+N	Vol+Váz	2 764	0	0.0					0.0
17	B+N	Vol+Váz	12 619	5 856	46.4	B	Vol	10 573	5 856	55.4
18	B+N	Vol+Váz	6 128	2 711	44.2	B	Vol	4 921	2 711	55.1
19	B+N	Vol+Váz	3 022	1 157	38.3	B	Vol	2 843	1 157	40.7
20	N	Váz	419	0	0.0					0.0
21	B+N	Vol+Váz	840	0	0.0					0.0
ukupno			159 481	62 427	39.1			108 023	62 427	57.8

The above calculation (Table 2) shows that the recovery ratio of geological reserves is low, around 58%. When geological and mineable reserves of the entire West Field deposit are compared, this recovery ratio is even lower, at the level of about 40% of the total geological reserves. Such low recovery ratio of the total coal reserves indicates that additional geological explorations should be initiated to define each tectonic block in this field, which would potentially increase the recovery ratio of the mining fields.

Physical properties of coal

Coal is of dark-brown colour, its cross-section is shelly and it does not stain fingers. The structure of coal is banded, partly grainy. In the deposit the coal is compact and viscous. If the coal is exposed to outside conditions for a long time, it crushes and crumbles easily.

At the outside temperature coal rapidly loses moisture. Thus from the average moisture content in the deposit of around 30%, this value falls down to 24% in the case of landfill coal.

Coal from the entire Sjenica basin, including the West Field, belongs to the type of brown coals labelled with ML.

Petrographic composition

Based on the petrographic composition and physical properties, coal belongs humus, semi-gloss, hard lignite.

Humic gel and ulminite represent the basic mass of coal of 75 - 80%.

Chemical properties

Basic chemical properties of coal include:

- Lower calorific value (LCV) ranging from 11,000 kJ/kg to 14,000 kJ/kg; in general it may be considered that the LCV of the deposit is 13.000kJ/kg;
- Deposit moisture is about 30%;
- Ash content 11 % and
- Total sulphur about 0.9%.

The total sulphur content in coal is 0.9 (%). Such a low sulphur value indicates that environmental measures should be undertaken in the case of large-scale coal combustion and ash disposal on landfills after its combustion.

Knowledge of the chemical composition of ash is of great importance for the safe formation of the ash and slag landfill of the future power plant. In addition, chemical composition of the ash plays a major role when it comes to the coal combustion in boiler plants.

It should be noted that the alkali content ($Na+K_2O$) higher than 0.5% damages boiler plants. An important role is played by the other metal oxides, for example increased SiO_2 content leads to the melting point increase. Combustion properties of ash from the West Field are favourable and offer the possibility of extensive coal utilisation in the combustion process.

The high meltability of coal ash indicates that this coal is good for all types of thermal processes. When it comes to the melting point impact on the combustion effects, coal from the West Field belongs to the group with poorly meltable ash.

4. POTENTIAL COAL MINING METHOD

When considering the entire Sjenica basin, its division into east, central and west fields, while respecting the structure and geometry of its coal seam, coal may be mined by applying underground and surface methods.

Underground mining is the primary method of coal mining in the West Field while surface mining as a secondary type of coal mining is possible in the East Field.

Development of a new Stavalj mine makes sense only when it is directly linked to the building of a thermal power plant at this location. Such symbiosis: a power plant and a secure energy source provides additional energy security of the Republic of Serbia and sustainable development for the local community. This involves the building of a 300MW thermal power plant. Depending on the selected capacity of the future power plant, the mine would have to ensure continuous coal production of some 2,000,000 t/year.

The required annual coal amount will indeed be influenced by the coal quality, i.e. energy source supplied to the future thermal power plant. Coal quality analyses conducted in the past in the West Field area indicate the consistent coal quality in terms of lower calorific value variations (LCV variation is only 8.18%). This means that the *guaranteed coal* supplied to the future thermal power plant would possess the following basic quality parameters:

- Moisture: 28.50 (%)
- Ash: 10.50 (%)
- Lower calorific value: 10,500 (kJ/kg)

4.1. Underground mining

West Field deposit opening and development

A new mine may be opened in two phases.

Phase I will cover the investigated part of the deposit characterised by a high exploration level and geological coal reserves of B category.

Deposit opening, as part of Phase I would be implemented in the north-western part of the coal zone, while the capital opening rooms or work areas, transport and ventilation incline would be built in the contact zone of the western and central fields. Another ventilation outlet would in fact be a link with existing N-1 incline in the active Stavalj pit. Total length of the opening and development rooms of the first geological block would be about 11,250m.

Phase II would be possible only after additional explorations of the remaining south part of the deposit, and identification of the mining contours of the entire West Field deposit. At this stage, the location of the new opening rooms would be determined covering the entire West Field. At this moment it is not yet clear what type of the opening room will be applied (vertical or inclined rooms). Main objective and primary function of this room is faster transportation of workers, materials and equipment. Deposit development (preliminary works required to establish the mining face) would be carried out from capital opening rooms exclusively within the defined tectonic blocks. Continuous operation of the thermal power plant requires secure annual coal production from the mine. This entails the purchase of two long-wall mining machines of up to

150m, with complete ancillary equipment. For each long-wall machine different preparations would be executed in terms of time and location.

Mining method

Coal would be mined on a large-scale, by utilising long-wall mining machinery. To achieve the required production capacity, the mining face must take into account the tectonic blocks geometry. This means that the face width may vary from 100m to 150m resulting in a high coal recovery ratio per block. Face height should not only take into account the necessary production but also the recovery ratio. Given that the average coal seam thickness is some 10m, horizon mining would be organised in the majority of the tectonic blocks, i.e. two 5m mining benches.

Investments schedule

Necessary investments for underground coal production of 2,000,000 tons per year, type of works and their schedule are presented in Table 3.

Table 3 Investments and their schedule per year (thousands of EUR)

Type of works	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Design docs	1.000	1.000	500				2.500
Mining rooms		15.000	7.687	7.687	7.687	3.000	41.061
Mining equipment		12.850	12.850	12.850	12.850	12.850	64.250
Surface structures		3.817	5.000	5.000	5.000		18.817
Surface equipment		1.320	3.000	3.000	3.000	3.000	13.320
Other		1.323	1.250	1.250	1.250	1.250	6.333
Total	1.000	35.310	30.287	29.787	29.787	20.100	146.281

Production capacity

Coal production in the future Stavalj mine from a single long-wall may be expected five years after the development of the investment - mining documentation.

The second long-wall would start producing coal in the seventh year. Thus it is possible to reach the production of 2,000,000 tons of coal per year in the seventh year, together with the coal production during the preliminary works period. Throughout the third and fourth years, coal would exclusively be produced from preliminary works i.e. mining face opening executed in the coal seam. Table 4 shows the production schedule.

Table 4 Production schedule

Coal production	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Tons	0	0	30.000	70.000	800.000	1.100.000	2.000.000

Underground coal mining workforce

The mine would operate in four shifts a day, its administration in three shifts, 350 days a year. Taking into account the daily schedule and the necessary workforce, including absence from work due to sick leaves, the required workforce would be as follows:

Long-wall works	200
Equipment and mining machinery operators	144
Worker and equipment transport	60
Electrical and mechanical maintenance	60
Outsourced workforce	50
Management and administration	60
TOTAL	574

4.2. **Surface mining**

Surface mining is considered as an alternative until the designed Stavalj mine capacity is reached.

Surface mine location and boundaries

The potential surface coal mine location is part of the East Field deposit outcrop at the site of the Stupsko Polje village. Stupsko Polje village is some 4km away from the main Sjenica - Novi Pazar asphalt road. Surface coal mining started in this area after World War II. This is the site with the shallowest coal seam dipping. Potential surface mine area is about 440ha. Possible stripping ratio is 4.9 m^3 (overburden/coal), with a maximum ratio of about 6.5 m^3. Surface mine boundaries have still not been defined while the estimated mineable coal reserves are some 5.5 million tons.

Mining schedule

The time of surface mine opening pit has not been considered. Hence the start of mining and the coal production schedule remain indefinite. Two-shift operation with 60 mine workers was foreseen. Potential available quantity of coal planned is at the level of about 400,000t. The mine would operate when coal production from the pit cannot cover the full designed capacity of the Stavalj TPP.

Operating life of the surface mine was not analysed at this moment.

Land acquisition, compensations and surface mine opening investments

Ownership structure and use of the future surface mine land (440ha) is unknown. Type and level of compensations are also unknown.

Surface mine opening investments may not be provided at this time for reasons of unclear surface mine operation purpose. The Technical Report prepared by the Czech company *Alta* states that the surface mine opening investments are EUR 30,000,000.

5. BASIC STAVALJ THERMAL POWER PLANT PARAMETERS

The building of a new thermal power plant with associated facilities, devices and necessary infrastructure is foreseen at the Stavalj mine location. Proposed concept of the new 2 x 150MWe power plant is based on the circulating fluidized bed technology. Thermal power plant should operate as a base load power plant within the Serbian power system.

Detailed studies (preliminary works, Prefeasibility Study and General Design and Feasibility Study and Preliminary Design) and analyses should demonstrate the feasibility and viability of this investment.

Thermal power plant would be supplied by brown lignite coal with calorific value of 10.5MJ/kg (±10%) from the pit. Coal consumption is estimated at 1.8 million t/year. Consequently, the planned building period should be aligned with building schedule of the mine and its coal production schedule.

The proposed thermal power plant would consist of two units, each with the net power of 120.42MWe. Primary fuel is coal, while fuel oil or heavy fuel oil would be used for boiler start-up and stabilisation.

Each unit includes a boiler (circulating fluidised bed and sub-critical steam parameters), with superheated steam turbine generator, deaerator, high and low pressure feed water heater and condensation and feed pumps, along with an integrated C & I system and water treatment system. The plant will be designed to operate as a base load power plant with a variable load.

Flue gases will be handled by electrostatic filters and subsequently emitted into the atmosphere. Condenser cooling would be provided through a closed cooling water system and cooling towers with natural air circulation. Cooling of the remaining parts of the boiler would be performed via a closed cooling water circulation system. All necessary aspects are taken into account in defining the technical power plant concept: coal, water, location conditions, selected location, emissions, and other aspects (power grid and logistics).

Coal:

- Consumption 1.8 mill. t/year
  - Grain size: 0 - 50 mm
  - Grain size distribution: 50% > 25 mm
  - Moisture content: 31.43% max 50%
  - Ash content: 14.34%
  - Sulphur content: 0.98%
  - Calorific value: 10,500 kJ/kg
  - Coal yard: two parts 200 x 50 m

Ash:

- Mine disposal, landfill next to the power plant or its reuse as building material
- Ash amount with limestone - 500 000 t/year.
- Heating system towards Sjenica: length 12 km, diameter 350 - 500 mm, capacity min. 15MWt, water temperature 60/120°C
- Reservoir: max volume 450 000 m^3
- Cooling water 160 -180 m^3/h
- Vapa River reservoir (pumping capacity max 2 m^3/min)
- Mine water for cooling purposes: max 30 m^3/min

Air emissions:

The plant will be designed in accordance with EU Directive 2010/75/EC stipulating the air emissions limits:

- NO_x: < 200 mg/m^3
- CO_2: < 200 mg/m^3
- Dust: < 30 mg/m^3

Operating life

- Minimum operating life is 25 years, with possible extension for another operating cycle of 25 years.
- Minimum service life of wearing parts is 2.5 years under continuous operation and unforeseen conditions.
- Units firing coal have a common number of operating hours of 7,000h annually.

Project scope

The present project generally involves complete engineering, equipment manufacturing, construction and commissioning of a turnkey power plant firing coal (generator outlet capacity) with two 150 MWe units based on the circulating fluidized bed technology (CFB). Table 5 shows the investments needed to build a CFB thermal power plant taking into account the different parts of the system.

Table 5 Circulating fluidised bed TPP unit building investments

	Item	EUR
1	Designing, equipment, building and erection works	184.300.000
2	Boiler, boiler room, coal supply, fly ash, water	179.450.000
3	Turbine, generator, turbine hall	58.200.000
4	Transformers, switchgear, control systems, electrical equipment	63.050.000
5	Auxiliary system	40.000.000
	Total	525.000.000

6. ENVIRONMENTAL MEASURES

Air emissions

A flue gas discharge system should also be considered. For this purpose, a stack should be constructed, while the basic technical characteristics should be provided in line with the design inputs. Directive 2010/75/EU stipulating emission limits of particulate matter for $>300MW_{th}$ thermal power plants is $<10mg/Nm^3$, and not $<30mg/Nm^3$ as stated. Therefore, the output concentration of particulate matter after the flue gasses handling system should be $<10mg/Nm^3$.

Surface and ground water emissions

The coal yard should be coated by an impermeable layer to prevent groundwater contamination.

Wastewater treatment plant should be designed to provide the outlet pollutant concentrations in line with the Decree stipulating the emission limit values of pollutants in water and deadlines for their achievement (OG RS № 67/2011 and 48/2012).

Soil emissions

The ash collection and disposal system should include environmental impact mitigation measures relating to the ash disposal.

Dry ash collection and delivery silos should be foreseen, together with the protection measures.

7. CONCLUSIONS AND RECOMMENDATONS

- The decision to go forward with the building of the new thermal power plant and coal mine Stavalj should be informed by the necessary documentation considering all project aspects;
- Further development of the documentation should involve preliminary works that preceding the development of the technical documentation stipulated by the Planning and Construction Law.

Literature:

[1]INITIAL ENERGY PROJECT STUDY “STAVALJ”
(mine + thermal power plant + transmission grid), Electric Power Industry of Serbia, 2013

UDK:622.7:666.952:658.566(045)=20

SnezanaVukovic[*], Zoran Kulic[*],

TECHNICAL AND ORGANIZATIONAL MEASURES OF PROTECTION AGAINST NOISE WITHIN MINING BASIN "KOLUBARA"

1. INTRODUCTION

In the industry of intensive mineral resources exploitation, both working and living environment are adversely affected. The noise impact is becoming increasingly more complex with the rise of production and engagement of more machines and great capacity equipment. Contemporary mining science, as well as practice, are facing the necessity of dealing with these extremely complex demands – application of new approach in terms of analysis, planning and conducting the protection measures against noise. The new approach is to be applied on both working environment of technological exploitation, preparation and processing systems for mineral resources, and living environment in the vicinity of technological mining complexes.

Excessive impact of noise is present in all phases of surface mining exploitation in the mining basin "Kolubara". The main noise comes from the mining machines for digging, transportation and ancillary work: excavators, loaders, bulldozers, conveyor belts, trucks, tank trucks etc.

In order to estimate the impact of noise, it is necessary to obtain detailed and precise data about the main parameters which treat noise as a physical phenomenon, and to continuously measure and track the values at its source, i.e. at the working environment. It is mandatory to regularly check health of the employees in terms of adverse effect of noise and its consequences.

2. DESCRIPTION OF TECHNOLOGICAL PROCESS

Kolubara mining basin is located in the central part of the Republic of Serbia, occupying West Sumadija region, between the populated locations and towns, Rudovci, Koceljeva, Lajkovac and Stepojevac.

In the mining basin „Kolubara", the coal is exploited on four open pits: Field „B/C", Field „D", „Tamnava-Zapadno polje" and „Veliki Crljeni" field.

Field „D" is the largest active open pit of the mining basin. Production of strip and coal is organised within four to five tailings systems used for stripping and two coal systems for digging coal. Stripping is done by the first ECS systems (excavator, conveyor, spreader). They are distributed according to production plans and field demands. The digged out strip is transported by track conveyors to the inner landfill of the pit, the area where the coal digging is finished. The second ECS system (excavator, conveyor, separation) is used to dig coal in the northwestern part of the pit.

The largest quantity of lignite is transported by rail, to power plant „Nikola Tesla" in Obrenovac, "Kolubara" in Veliki Crljeni and "Morava" in Svilajnac. Smaller quantity is used for consumers.

a. Sources of noise at the open pit Field “D”

Bucket-wheel excavators:

- SRs 1200x24/4+VR (G-IV , G-III)
- SRs 1201x24/4+VR (G-II)
- SRs 1300x26/5+VR (G-VIII)
- SRs 1301x24/2.5 (G-X)
- SchRs 630x25/6 (G-VII)
- SchRs 1760x32/5+VR (G-IX)

Belt wagons:

- BRs1600/ (28+50)x15 (BW1)
- BRs1600/ (28+50)x1 7 (BW2)

Draglines:

- ЕШ 5/45 (21, 22, 23)
- ЕШ 6/45 (27, 29, 31)
- ЕШ 10/70 (10,11)

Belt conveyors:

1. ECS system		2. ECS system
1.2=806 m	C.6.=377 m	A.6=9,36m
B.15=6 18m	B.13= 514m	B.11=976m
B.27= 791m	C.8=509m	B.19=435m
B.10= 298m	2.2=386m	C.9=540m
1.9 =486m	C.14=478 m	C.10=410 m
B.8=1350m		

1a. ECS system	*1b. ECS system*	*1c. ECS system*	*1d. ECS system*
B.25=633m	B.14=470m	B.6=399m	A.18=1274m
B.4=524m	A.7=372m	A.12=137m	A.23=784m
A.8=739m	1.1=470m	B.9=673m	A.21=365 m
C.3=905m	B.28=387m	C.7=519m	A.22=677 m
		1.9a=607	A.19=684m
			A.20=745m
			C.15=298m

Spreaders:

- A_2RsB 3500x60+BRs (O-I, O-IV, O-II)
- ARs 1800/(14+33+60)x20 (O-VI)

2.2. Estimation of potential danger and the expected impact on workers

The impact of noise can be seriously threatening to workers' health. Application of the adequate measures of protection, whether they are technological, technical or organisational, mostly depends on the estimation of the potential impact of new technologies on working environment, i.e. on water, air and soil, as well as working environment within all mining areas.

Technological process of surface mining of coal and strip at the Field "D" causes a certain level of production of harmful matter (mineral dust) and noise.

At a workplace that assumes noise above 85 dB, people can be hired only if they had a specialised medical check up and confirmed capable of working at such places. If the noise cannot be reduced below 85 dB, the employee who is exposed to this level of noise on a daily basis, is entitled to medical hearing tests (to check if the ability is preserved), as well as to complete medical check ups.

All employees who are working under a certain health threatening factor need to be medicaly examined on a regular basis, including the audiometric testing.

2.3. Results for noise level measuring at the open pit

The above mentioned measuring is done within regular workplace checkups during summer period in 2013, done by an authorised company.

Table 1: Results for noise level measuring at specific locations

SITE	INTERNAL LABEL	SCREENED LOCATION	LEVEL OF NOISE [dB]
Drive station	B-9	Operator's cabin	71
Drive station	B-9	Station platform	90
Drive station	A-7	Operator's cabin	75
Drive station	A-7	Station platform	94
Drive station	B-6	Operator's cabin	72
Drive station	B-6	Station platform	90
Drive station	C-3	Operator's cabin	73
Drive station	C-3	Station platform	95
Bucket-wheel excavator	G-4	Circular platform	88
Bucket-wheel excavator	G-4	Near the excavator	79
Bucket-wheel excavator	G-4	Excavator operator's cabin	66
Bucket-wheel excavator	G-4	Loading belt operator's cabin	62
Bucket-wheel excavator	G-4	Day room	67
Bucket-wheel	G-4	Electrical room	73

excavator			
Spreader	O-1	Circular platform	87
Spreader	O-1	Input conveyor operator’s cabin	64
Spreader	O-1	Output conveyor operator’s cabin	65
Spreader	O-1	Day room	69

Noise level at almost all drive stations is significantly above the required (85dB). The level is even higher when some ancillary machines are working (bulldozers, pipelayers, diggers), or machines and equipment are being repaired, or if a great number of machines is active in a small space. The level of noise is considerably higher if the equipment and machines are old. The workers’ age is also relevant for the tendency to damagen hearing, even though deterioration can happen at any age.

3. NOISE IMPACT ON THE WORKING ENVIRONMENT

Noise is measured in rooms and spaces with closed doors and windows, with an active venting system, or air conditioning device. If the workplace is commonly used with doors or windows open, the measurement should be done under such circumstances, as well. Noise in the working space is measured during normal operation of machines and equipment.

If the level of noise at a certain location oscillates during working hours for at least 3 dB, measurement needs to be repeated for all working regimes of machines, devices and equipment which is used at the location.

Noise measurement is done with the microphone set at the exact position of the worker doing his job, at ear level, 0.20 m from the worker’s ear. The microphone needs to be directed to the source of noise. There should be no obstacles between the microphone and the source.

If the working spot is not specifically determined on a location, the measurement is done on the spot which is commonly used for doing the specific job. If the workers stand, the noise is measured at 1.6 m, or at 1.2 m if they sit during their work

When a worker’s job comprises duties with different levels of noise, or volume changes for more then 2 dB during the working day, the level of noise is measured or counted during the most characteristic process, or during the working hours, if a noisy operation is not likely to be repeated during the working day.

If a worker is exposed to noise at a different scale during the week, so that the measured level can be deceiving when the health threatening factors are calculated, daily results Lrd are used to calculate the weekly estimated level.

The place and time of measurement should be chosen so as to be typical for the average worker’s exposure to noise and described in records as precisely as possible.

When levels of noise are acidentally changed at a location (open pit, repair workshops, etc.), Lr can be assesed by short-term measurements, at random during day or week.

If a worker operates on different locations where levels of noise significantly vary, preference is given to measurement with personal dosimeter, which is carried by the worker during the whole operation.

A working space is checked for noise at as many spots as needed to estimate the health threatening risks for all employess working in that working space.

3.1.Measures of protection on tools and devices

Working tools and devices that create noise during operation, must comply with the acoustic requirements.

Tools and devices must be produced as to avert noise which is created by their straight line and rotational movements, or noise which is transmitted through the construction to ground or other elements of the working space where such tools and devices are located.

If compliance with requirements implies special measures (silencers, flexible relining, sound absorbing shields, isolation cabins, etc.), the documentation for such tools and devices needs to clearly state those measures.

In order to hinder noise which is created by movement of fluid (air, steam, gas) through pipes or chanells, or their discharge in the athmosphere (internal combustion engin, steam engin, air compressor, blower, fan, etc.), certain measures are applied within design, construction and installation of pipelines (adequate shaping of channels; separation of pipelines from sources of noise and other elements of a room using rubber padding or similar materials that can absorb sound; installation of silencers at the exhaust etc.)

In order to prevent noise which is generated by transportation vehicles in closed space areas (bridge cranes, railway wagons, motor carts, handcarts, etc.) certain measures are applied (laying crane tracks on elastic surface, connecting rail by welding, cladding metal wheels by rubber or other resilient material which absorbs sound, paving the main roads in the halls and workshops if they are made of concrete or other hard materials, etc.)

Before the standards for measuring machine-made noise are created, all data about the noise made by tools and devices is collected based on the measurements which comply with ISO references.

3.2.Measures of protection on facilities at the workplace

Facilities which will house tools and devices that create noise, or which can be permeated with noise from the outside, need to be acousticly compliant with the relevant technical regulations and acoustic calculations which are attached to the project documentation for the facility.

Measures of protection will be practiced during reconstruction of facilities, workplaces and technological processes, as well as during installation of new tools and devices in the workplaces, should this installation, or reconstruction cause exceeding the approved level of noise.

Users of new and reconstructed facilities with workplaces that house tools and devices that create noise, must measure the level of noise in the working spaces before they put the machines into regular operation, in order to avoid exceeding the allowed level of noise.

If a worker is exposed to noise volume above 85 dB, or the acoustic pressure exceeds 200 Pa, individually or simultaneously, necessary precautions must be provided:

1) workers and/or their representatives in companies or institutions must be informed, or even adequately educated about the following:
    - possible threat to hearing;
    - regulations about measures of protection in such cases
    - wearing personal protection
    - hearing tests and check ups

2) workers and/or their representatives in companies or institutions must get the results of estimated or measured noise level, and the assesment of its impact on workers' hearing.

At a workplace that assumes noise above 85 dB, workers shall be adequately informed (by signals, drawings, images, etc.) where, when and how to apply the protective measures against noise.

At a workplace that assumes noise above 90 dB or the acoustic pressure over 200 Pa, workers shall be informed by certain signals about the current situation and the ways to apply the protective measures. Such sites should not allow access to workers who are not directly connected to operational processes of this working position.

If the noise level changes significantly from day to day, the company is entitled to request from the republic authority to shift the allowed limit of the noise level, but only if the adequate controls approve that the aproximate exposure to noise per day is not exceeding the values proposed by regulations.

In specific cases, when technical and/or organisational measures cannot lower daily exposure to noise under 90 dB and provide the adequate protection, authorities can postpone the application of regulations for some time. These exceptions can last six months maximally and they can be repeated. In such cases, all means of personal protection with the highest level of efficiency must be used.

3.3.Personal protection against noise

In a working space where acoustic requirements cannot be fullfiled, either because of technical or technological conditions of exploitation, or on other reasonable grounds, the exposed workers need to be provided with hearing protectors which are assumed in Code of personal protection and safety at work and personal protective equipment, i.e. valid Yugoslav standards, whereby meeting the following requirements:

1. If the level of noise exceeds 90 dB, or the acoustic pressure exceeds 200 Pa, means of personal protection need to be used (protectors).
2. If there is a possibility that noise will exceed the allowed level of 85 dB, workers need to be provided with means of personal protection.
3. Employer is obliged to provide the sufficient number of personal protectors.

   The protectors can be chosen in cooperation with the interested workers and must be suitable for each worker, with the aim of health protection and safety at work.

   These protectors need to impede the noise level (or maximal acoustic pressure) and keep it under 85 dB.

Personal protective gadgets, such as antiphons and ear plugs, are not suitable for most of the operations in the opet pit. Excavator, bulldozer and conveyor operators must be focused on receiving the dispatcher's or chief's instructions, so to be able to react on time when they need to move or stop the equipment, excavators, bulldozers or conveyors. It is also very important that they follow the sound signals which may call for an alert in the open pit, announce danger for workers in the vicinity, or danger from fire, as well as other emergency situations.

3.4.Standardized values

Measured (relevant) level of noise is determined by measurement of an equivalent level of noise, or just A-level of noise, that is corrected for different types of noise.

a) Noise with a steady level (without impulse or tones) has the same measured (relevant) level as the mean level, assesed by a precise phonometer including the usage of correction filter A, with fast response during the measurement interval. Table no. 2 features numbers that represent the allowed duration of exposure to certain levels of noise.

Table no. 2: Permitted duration of exposure to certain levels of noise

Daily exposure in hours	Level of noise in dB
8	85
6	87
4	90
3	92
2	95
1 1/2	97
1	100
1/2	105
1/4	110
1/8	115*

b) If the noise level is variable, measured (relevant) level is determined by this formula:

$$L_{eq} = 10\lg_{10}\left[\frac{1}{N}\sum_{i=1}^{n} N_i 10^{0,1 L_{Ai}}\right] dB(A)$$

whereby:

Leq – is an equivalent level of noise in dB

LAi – is the sound level in dB corresponding to mean value of the class interval with a possible span of 2, 3, 4 or 5 dB

Ni – number of results belonging to class "i"

N – total number of results in the course of noise measurement

n – number of class intervals which includes all measured levels.

Level of noise LA is measured by precise phonometer, including the corrective filter with A-characteristic and the fast response.

c) Impulse noise of steady or changable level is determined as in case a) or b), only the measurements are done by a precise impulse phonometer.

If the impulse noise is measured with the precise phonometer with fast response, the measured (relevant) level should be determined by adding 5 dB to the calculated mean value, or to equivalent level.

d) Tonal noise of steady or changable level is determined as in case a) or b), only the measured (relevant) level should be determined by adding 5 dB to the calculated mean value, or to equivalent level.

e) For the interrupted noise, the first equivalent level is determined in the same way as for the noise with variable level. Also, the second equivalent level should be determined separately for the period when the noise is at its highest value (when all sources of noise are active). When the equivalent level Laeq is determined this way, it should be subtracted by the value DL, which depends on duration of the highest value of noise within the measured interval. The values for DL are presented in the next table:

Table no.3: Duration of the noise level

Duration of noise amplification within the measured interval	50-100%	25-50%	10-25%	10%
Subtraction by DL in dB	0	3	6	10

When opting between the first and the second equivalent levels, we should consider the higher level as the measured (relevant).

f) When noise is measured at several spots, the result is calculated as an arithmetical mean value of all the measurements, i.e. equivalent levels of noise at the spots, if all the values are in the range of 6 dB. Otherwise, all results need to be presented separately, in tables.

g) Results of noise measuring, i.e. determination of equivalent level of noise with a decimal number values, should be rounded in a way that decimals below 5 are merely omitted, while decimal 5 or above should imply the rounding to the next integer.

3.5.Method of analysis and evaluation

Harmful noise is a sound with a level (measured in a certain working space in dB) that exceeds the allowed level of noise according to regulations. Noise is considered to have adverse effect if it hinders various operations, prevents hearing/making immediate conversations, or using means of communication (phone, radio, etc.), hearing sound signals and damages hearing ability.

Harmful effect of noise is highly probable at all stages of open pit exploitation. Sources of noise being various mining machines for digging, transportation and ancillary work: excavators, loaders, bulldozers, conveyor belts, trucks, tank trucks etc.

Open pit field “Tamnava- zapad” is not likely to endanger the environment by vibrations, since excavation of lignite is not done by mining, but the continuous operation on the pit.

However, vibrations from the operating mining machines is present and restricted to the working environment only.

Level of noise L is defined by the formula:

$L = 20\ 1g(p/p0) = 10\ 1g(w/w0)$

whereby

p – is the pressure of sound waves on the spot with level L and p0= 20 mPa,

w – is the intensity of the sound waves at the spot with level L, and w0=10-12 W/m2. Level is expressed in decibels, dB, or with decibel A, dBA, if the measurement involves frequency filter A.

Everyday exposure and the average weekly exposure to noise can be calculated this way:

$$L_{EP.d} = L_{Aeq.Te} + 10\ lg_{10} \frac{T_e}{T_o}$$

whereby:

LAeq.Te – is the equivalent level – average energy value of a sound wave during an interval "ti" and is defined in the equation:

$$L_{Aeq.Te} = 10 lg_{10} \left\{ \frac{1}{Te} \int_0^{Te} \left[\frac{P_a(t)}{P_0} \right]^2 dt \right\}$$

Te – daily duration of exposure to noise

To – 8h = 28,800 s

Po – 20 mPa

PA – current and weighted acoustic pressure A, expressed in Pascals (Pa), to which a person is exposed at the atmospheric pressure and who can, but not necessarily, move from one spot to another during his work.

Acoustic pressure is determined by measurments at the locations where workers operate, at ear level, (article 20, paragraph 1), without the presence of workers, if possible. The measuring method allows least aberrations in the sound field.

If a microphone needs to be positioned very close to the body, it is set in such a way that it doesn't change equivalent field of sound pressure.

When daily exposure to noise is being measured, any personal protector (which could distort the results), should be removed.

b) average weekly level of daily LEP.n (exposure) is formulated like this:

$$L_{EP.n} = 10 lg_{10} \left[\frac{1}{5} \sum_{k=}^{m} 10^{0,1 (L_{EP.}d)K} \right]$$

whereby:

(LEP.d)K values of LEP.d for each out of m working days in the observed week

1) measured (relevant) level Lm is the level of noise which is measured at a certain time and a certain point;

2) measured (relevant) values Lmi are measured (relevant) values of short random measurements within "n" samples;

3) the assesed level Lr is an equivalent level which includes a correction because of the impulsive characteristic of sound, also considering the workplace and time component, thus being characteristic of a real risk to workers during their usual working routine.

4) the assesed daily level Lrd regards the exposure to noise during 8 h per day, or 28.800s;

5) exposure is the time during which sound affects a worker on a working day, or week

6) index "i" denotes a level L, which is characteristic of a time interval t whitin which the level of noise is changed for less than 2 dB, as well as for weekly exposure of workers. It is used when a worker is not exposed to noise each day of the week, or if the levels of exposure considerably vary during days of the week. Index "K" stands for a day in a week;

7) level Lg is allowed by regulations as a limit, in order to protect workers against injuries and health threatening factors, or excessive interference with work;

8) current level Lp is the highest level of a variable sound, measured with a device set to the option "peak";

9) allowed current level Lgp is allowed by regulations and limitted for certain sound effects (explosion, sharp blow) in order to protect hearing from damaging or if a worker is exposed to it only once or very briefly;

10) dinamics of measuring device is defined by a response time constant. "Fast" dinamic assumes time constant 0,125 s, while "slow" dinamic assumes 1s;

11) excessive level is above limits which are proposed in order to protect hearing from damaging or health deterioration caused by noise, that can lower one's ability to work;

12) personal dosimeter is a measuring device which workers take with them, to measure LAeq (equivalent noise).

3.6.Determination of measuring interval

Measuring interval is determined by type of noise. It is required that the minimal measuring interval should be long enough to encompass the entire cycle of changes in noise levels. Changable noise is measured at three intervals per day, and twice per night. Maximal measuring interval during day is from 6 a.m. to 10 p.m, or it can last from 10 p.m till 6 a.m. during night.

3.7.Instruments for measuring and analysing noise

Measuring instruments need to fulfill the requirements IEC 651 and IEC 804 for integrating measuring instruments of "P" category.

An instrument must be able to measure Leq, in order to measure changeable levels of noise.

An instrument should enable measuring levels with A filter, of linear level, as well as the octave analysis within the octave frequency range from 16 Hz to 16 kHz.

3.8.Measures of protection against noise at the open pit Field "D"

Occurence of the adverse effect of excessive noise at a workplace is present in all phases of surface mining exploitation at the open pit Field "D". In order to provide adequate protection for workers and local population from excessive noise which is generated by technological process of exploitation, it is necessary to sistematically apply the protective measures. These measures comprise:

- Control of the noise level within the mining locations and nearby settlements;
- Reduction of noise at specific facilities and machines;
- Application of acoustic protection, by setting the physical barriers or fences, and
- Usage of personal protective equipment for employees at the open pit.

Measures of protecion for diminishing negative impact of noise on the working and living environment comprise:

- Reduction of noise at the very source, by using quieter machines or methods of work (which could help lower the expenses meant for installment of large and costly barriers and prevent operating space narrowing and all the problems this may cause);
- Distribution and usage of equipment should be carefully considered, so that the equipment is located as far as possible from the noise vunerable areas (even though distribution of equipment and access roads are planned in advance, daily set up of the equipment at a

certain location and the way of usage should be frequently controlled by the operators, who should play a more active role in decreasing noise);

- Modification of the existing facilities and equipment (with manufacturers' approval);
- Necessity of decreasing noise should be widely mentioned and pointed out;
- Regular and efficient maintenance of equipment can remarkably reduce noise which is created by old machinery and equipment at the open pit;
- Mining machinery motors should be equiped with silencers, maintained and used according to manufacturers' instructions, in order to prevent creating excessive noise;
- If a noise level in nearby towns exceeds the allowed values, it is necessary to install sound barriers between the open pit and the town;
- If possible and feasible, source of noise should be enclosed, which depends on the type of source;
- Certain operations should be limitted to special locations;
- It is necessary to provide hearing protection equipment for workers, so to prevent consequences from the excessive noise.

Mining equipment which is used in surface mining exploitation at Field "D" creates considerable noise that can be reduced by application of certain measures, assuming an agreement with manufacturers. Those measures are:

- Adaptation and modification of machine motors' exhaust branches and pipes with the aim to decrease the level of noise;
- Acoustic insulation of metal parts of the equipment;
- Enclosure of machines and devices, etc.

Education of employees is very important in terms of emphasizing the necessity of noise reduction to levels proposed in regulations, and about the health threatening effect of the excessive noise.

Trainings about equipment maintenance and regular operation, as well as about the necessity and ways to use personal hearing protectors, are also significant for workers.

4. CONCLUSION

Excessive impact of noise at workplace is present in all phases of surface mining exploitation at the Field "D". Main sources of noise are mining machines for digging, transportation and ancillary work: excavators, loaders, bulldozers, conveyor belts, trucks, tank trucks etc.

Regulations on protection against noise comprise a system of technical and organisational protective measures against noise. The act of risk assesment assumes health protection measures which include these criteria as well, i.e. the adverse effect of excessive noise during operations at the open pit, while considering variety of professions and job descriptions within usual working processes at the pit.

How comfortable and safe will the working environment be, depends on many factors, such as correct choice of equipment, technology and exploitation machines, maintenance, control of noise level within the mining sites and nearby settlements, enclosure of noise sources (depending on the type of noise) and application of personal protective measures.

These facts are showing the complexity of the problem, demanding application of the existing measures, but alongside considering new approaches to analysis, planning and application of protective measures against noise in the working environment, as well as living environment in the vicinity of technological systems of open pits. It is highly recommended that the importance of noise reduction should be widely mentioned and permanently emphasised.

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SYSTEMATIZATION OF THE INJURIES IN UNDERGROUND COAL MINES IN SERBIA IN 2013.

Abstract

This paper presents a detailed analysis of injuries in underground coal mines in Serbia in 2013. Injuries are analyzed numerically by category and weight, place, causes, for parts of the body, qualification and age structure and organizational factors, and are based on the value of the same date the appropriate datasheet of the recommendations for appropriate measures in order to improve safety.

Keywords: mine, coal, occupational health, injury

1. INTRODUCTION

Work at coal underground system of exploitation is associated with a number of hazards to life and health of employees, which includes:
• presence and the sudden appearance of a variety of explosive, poisonous or asphyxiating gases,
• potential risk of fire and explosion in character and intensities,
• sudden incursions of ground and surface water and sludge,
• large and frequent temperature changes and mirkoklimatske working conditions,
• cramped workspace, under artificial lighting and insufficient, in terms of increased noise and vibration,
• danger of caving and backfilling work space and others.

All of these factors are constantly present and required significant efforts to reduce their impact or eliminate it. However, despite the technical steps the possibilities for hazardous and harmful effects of factors on the working conditions of employees and the occurrence of accidents and injuries to employees are not excluded.

The narrow field of research in this paper are underground coal mines in Serbia, and as a source of data, the data from the monthly and annual reports of injuries, which is statistically processed and analyzed.

In Serbia, the technological processes of underground exploitation excavated layers of stone, brown coal in 11 undermines, where the excavation apply upright and column-chamber systems excavation in different variants. Mainly the excavation of thick coal seams having a significant impact on the safety and protection of employees.

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2. INJURIES AND COLLECTIVE ACCIDENTS IN MINES

The technological process of underground coal mining work includes a series of interconnected operations and coordinated in time and space by opening research, preparation, excavation, transport, export and processing as core processes and supporting: ventilation, drainage, delivery and shipping of raw materials, transport of employees and others. Modern mine is a complex production system on the extraction and processing of coal, which interact in complex workflows. In the design of such a complex production system takes into account the modern achievements of science and technology, taking account of their adaptability to the work environment.

Collective and individual injury accidents may be caused by a number of influencing factors or causes of injury can be classified into three groups:

- Natural, which are dependent on the natural geological conditions in the reservoir,
- technical and technological, which depend on the level of applied engineering and technology,
- subjective, dependent on the participants in the work process.

All of the above causes and sources are in direct violation of the spatial and temporal relationship, which means that injuries and collective accidents occurring as a result of combined effects of unfavorable factors from all three aforementioned groups of pathogens. In order to define spheres of influence in the real situation and proper routing of preventive activities, each group of possible causes must be thoroughly parsed and especially to observe and analyze.

When you solve any real problem of protection and security work in the mines, natural and technical-technological factors, it is necessary to analyze the maximum and realistic assessment of possible negative effects on the functioning of the technological process and the emergence of potential hazards employed. In this way only can reduce the level of risk or eliminate them completely, so the error (inattention, improper operation ...) employees could not lead to the activation of the emergency and bring with them unintended consequences.

Specifically cited in the literature is that even more than 80% of the causes injury makes the human factor. But the fact is that the development of technology, as well as funds of collective and personal protection reduces the number of occupational injuries and accidents collective significantly eliminated. It should also be borne in mind that modern technical equipment requiring higher educated and professional level of employees, and thus improves the understanding of and relationship to Safety and technical protection in underground coal mines.

3. ANALYSIS OF INJURY IN 2013

Injuries in underground coal mines in Serbia are shown in Tables 1-10, while in Table 11 presents the lost wages and working injury absence. In 2013, coal production was from 601 439 tku, with cave and made 463 280 733 144 total wages.
Detailed analysis of injury employed in underground coal mines in Serbia noted a number of weaknesses of existing technological processes of exploitation, which resulted in a high incidence of injuries and unsafe working environment.

In addition to showing the number of violations by mines and their classification according to severity (mild, severe, death and total) categorization of injuries can be expressed through other indicators. The research results obtained by different factors and mines for the year 2013 are shown in the following table.

Table 1. Injuries on heavy

Mine	Rang of injuries			
	Lake	Heavy	Dead	Total
Vrška čuka	15	-	-	15
Ibarski rud.	5	1	-	6
Rembas	142	20	1	163
Bogovina	22	3	-	25
Soko	83	4	1	88
Jasenovac	19	5	-	24
Lubnica	38	1	-	39
Štavalj	55	6	-	61
Aleksinac	99	9	-	109
Total UEC	479	49	2	530

Table 2. Injuries by technological stages of work in mine

Mine	Technological stages of work in mine							
	Excavation	Preparation	Servicing	Tran-sport	Deliveru	JVŽ	Undermine	Total
Vrška čuka	-	1	4	4	2	-	1	12
Ibarski rud.	-	-	2	-	1	-	-	3
Rembas	21	16	4	24	21	9	35	130
Bogovina	4	2	4	-	3	-	10	23
Soko	9	11	9	13	28	-	3	73
Jasenovac	6	10	-	-	1	-	5	22
Lubnica	6	8	3	4	5	-	8	34
Štavalj	9	6	1	6	7	-	26	55
Aleksinac	3	62	8	2	22	-	12	109
Total UEC	58	116	35	53	90	9	100	461

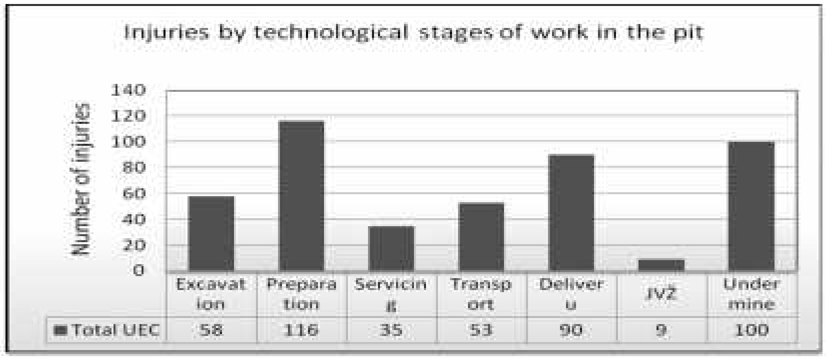

Table 3. Injuries based on qualification structure of employees

Mine	Qualification structure of employees						
	VSS	SSS	VKV	KV	PK	NK	Total
Vrška čuka	-	-	-	7	2	6	15
Ibarski rud.	-	-	-	2	1	3	6
Rembas	-	5	5	62	32	59	163
Bogovina	-	2	-	13	3	7	25
Soko	-	2	-	31	15	40	88
Jasenovac	-	-	-	11	7	6	24
Lubnica	-	1	1	16	5	16	39
Štavalj	-	2	-	26	5	28	61
Aleksinac	-	2	2	55	27	23	109
Total UEC	-	14	8	223	92	193	530

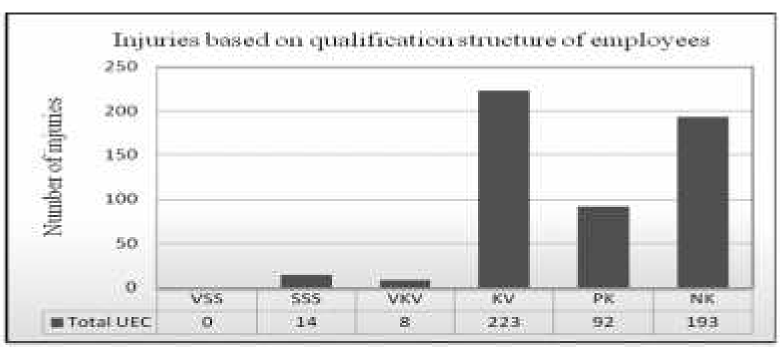

Table 4. Injuries by body parts

Mine	Injuries by body parts								
	Head	Face	Eye	Internal organs	Arm	Leg	Chest and back	Other	Total
Vrška čuka	-	1	-	1	7	6	-	-	15
Ibarski rud.	-	-	-	-	4	2	-	-	6
Rembas	14	11	2	2	58	65	11	-	163
Bogovina	-	1	-	-	14	3	2	5	25
Soko	7	-	1	1	34	35	10	-	88
Jasenovac	3	-	-	-	9	9	1	2	24
Lubnica	4	3	3	-	11	14	-	4	39
Štavalj	7	1	2	-	17	26	2	6	61
Aleksinac	7	1	1	-	42	38	17	3	109
Total UEC	42	18	9	4	196	198	43	20	530

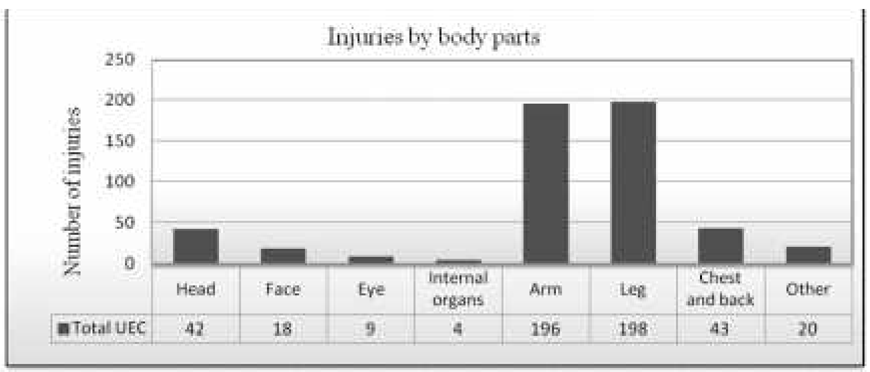

Table 5. Injuries by source of injury

Mine	Source of injury							
	Machin -ery	Electrical equipment	Machines for transport	Roof support	Rope	Fall	Other	Total
Vrška čuka	-	1	2	2	1	4	5	15
Ibarski rud.	-	-	2	-	-	1	3	6
Rembas	50	7	-	18	3	28	57	163
Bogovina	4	2	2	10	-	3	4	25
Soko	6	2	5	23	-	3	49	88
Jasenovac	7	-	1	1	-	1	14	24
Lubnica	2	-	4	5	-	11	17	39
Štavalj	14	4	1	6	-	18	18	61
Aleksinac	25	3	-	35	-	21	25	109
Total UEC	108	19	17	90	4	90	47	530

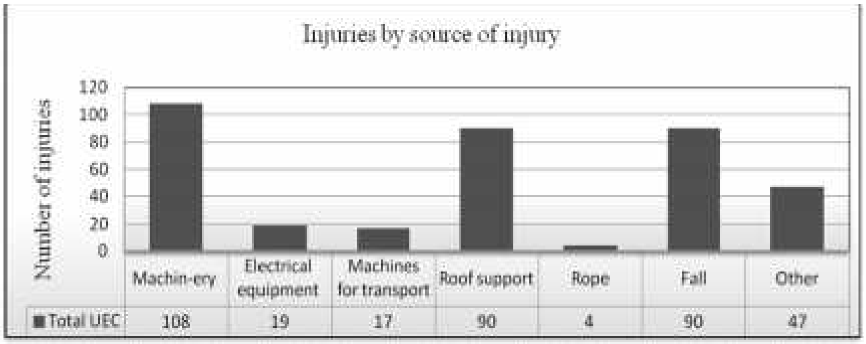

Table 6. Injuries by age

Mine	Age							
	20-25	26-30	31-35	36-40	41-45	46-50	≥ 50	Total
Vrška čuka	2	-	2	4	2	3	2	15
Ibarski rud.	2	1	-	1	1	-	1	6
Rembas	25	34	18	19	27	18	22	163
Bogovina	3	1	2	7	9	2	1	25
Soko	3	8	22	22	14	14	5	88
Jasenovac	-	7	3	7	5	1	1	24
Lubnica	-	7	3	4	12	8	5	39
Štavalj	9	11	10	13	7	5	6	61
Aleksinac	5	10	17	21	20	15	21	109
Total UEC	49	79	77	98	97	66	64	530

Table 7. Injuries by month of the 2013 year

Mine	Month												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Vrška čuka	2	1	4	1	-	2	2	1	-	-	1	1	15
Ibarski rud.	-	-	-	-	-	2	-	-	1	3	-	-	6
Rembas	10	15	19	11	15	14	15	12	10	13	13	16	163
Bogovina	4	2	5	-	-	2	3	3	3	-	1	2	25
Soko	4	6	7	11	1	10	7	9	6	13	7	7	88

Jasenovac	3	-	2	2	1	1	6	2	4	2	1	-	24
Lubnica	1	5	4	5	5	4	2	3	1	7	1	1	39
Štavalj	3	1	4	4	8	4	3	4	10	5	7	8	61
Aleksinac	4	14	9	16	6	10	5	10	6	12	8	9	109
Total UEC	32	44	54	30	35	49	43	43	41	56	40	44	530

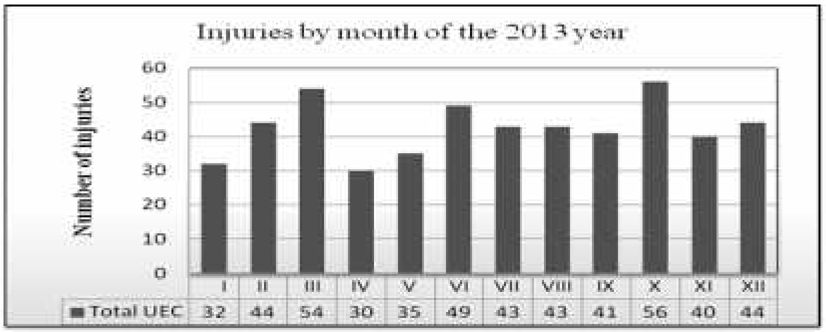

Table 8. Injuries by days of the week

Mine	Days							
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total
Vrška čuka	2	3	6	2	1	1	-	15
Ibarski rud.	-	1	2	-	1	-	2	6
Rembas	29	20	32	17	18	22	25	163
Bogovina	6	4	1	4	5	5	-	25
Soko	8	10	15	14	14	12	15	88
Jasenovac	3	2	3	5	4	1	6	24
Lubnica	4	6	8	5	5	7	4	39
Štavalj	9	11	8	9	6	7	11	61
Aleksinac	15	17	18	13	19	14	13	109
Total UEC	76	74	93	69	73	69	76	530

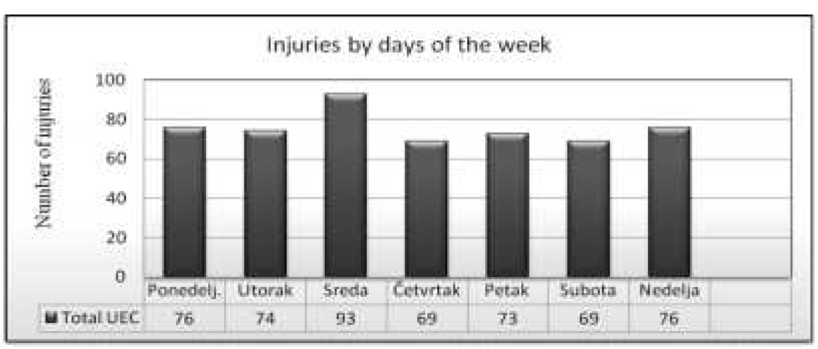

Table 9. Injuries shifts

Mine	Shifts			
	I	II	III	Total
Vrška čuka	11	2	2	15
Ibarski rudnici	3	2	1	6
Rembas	19	50	34	163
Bogovina	13	8	4	25
Soko	28	33	27	88
Jasenovac	16	7	1	24
Lubnica	17	11	11	39
Štavalj	23	27	11	61
Aleksinac	34	43	32	109
Total UEC	224	183	123	530

Table 10. Injuries on hours of work

Mine	Work hours								
	1	2	3	4	5	6	7	8	Total
Vrška čuka	1	2	1	3	4	3	1	-	15
Ibarski rud.	-	3	-	2	-	-	1	-	6
Rembas	12	25	25	30	19	20	24	8	163
Bogovina	2	3	6	8	3	2	1	-	25
Soko	7	5	19	14	6	18	10	9	88
Jasenovac	3	5	3	5	5	3	-	-	24
Lubnica	4	9	3	9	4	5	5	-	39
Štavalj	3	6	10	15	14	9	3	1	61
Aleksinac	6	15	13	30	17	23	5	-	109
Total UEC	38	73	80	116	72	83	50	18	530

Table 11. View of lost wages due to sick leave in the mines JP PEU in 2013.

TYPES OF SICK LEAVE	VRŠKA ČUKA			IBARSKI RUDNICI			REMBAS		
	In mine	Out of mine	Σ	In mine	Out of mine	Σ	In mine	Out of mine	Σ
Under 30 days	915	804	1.719	2.287	852	3.139	12.394	2.561	14.955
Injuries	188	51	239	104	35	139	2.890	317	3.207
Illness	727	753	1.480	2.183	817	3.000	9.504	2.244	11.748
Over 30 days	261	139	400	507	267	774	2.483	1.263	3.746
Injuries	166	32	198	141	121	262	1.402	365	1.767

Illness	95	107	202	366	146	512	1.081	898	1.979
Total	1.176	943	2.119	2.794	1.119	3.913	14.877	3.824	18.701

Second part of table 11.

TYPES OF SICK LEAVE	BOGOVINA			SOKO			JASENOVAC			LUBNICA		
	In mine	Out of mine	Σ	In mine	Out of mine	Σ	In mine	Out of mine	Σ	In mine	Out of mine	Σ
Under 30 days	4.245	904	5.149	5.329	2.045	7.374	2.813	1006	3.819	2.548	896	3.444
Injuries	605	85	690	1.725	186	1.911	510	122	632	574	24	598
Illness	3.640	819	4.459	3.604	1.859	5.463	2.303	884	3.187	1.974	872	2.846
Over 30 days	919	542	1.461	2.204	735	2.939	765	163	928	2.073	495	2.568
Injuries	418	92	510	1.380	136	1.516	492	39	531	889	-	889
Illness	501	450	951	824	599	1.423	273	124	397	1184	495	1.679
Total	5.164	1.446	6.610	7.533	2.780	10.313	3.578	1.169	4.747	4.621	1.391	6.012

Third part of table 11.

TYPES OF SICK LEAVE	ŠTAVALJ			ALEKSINAC			Total UEC		
	In mine	Out of mine	Σ	In mine	Out of mine	Σ	In mine	Out of mine	Σ
Under 30 days	5.221	2.693	7.914	9.772	545	10.317	45.524	12.306	57.830
Injuries	1.541	112	1.653	6.361	132	6.493	14.498	1.064	15.562
Illness	3.680	2.581	6.261	3.411	413	3.824	31.026	11.242	42.268
Over 30 days	49	13	62	843	233	1.076	10.104	3.850	13.954
Injuries	-	-	-	-	-	-	4.888	785	5.673
Illness	49	13	62	843	233	1.07	5.21	3.065	8.28

						6	6		1
Total	5.270	2.706	7.976	10.615	778	11.393	55.628	16.156	71.784

From the presented data, performed analysis shows that the highest number of injuries resulting carelessness and unsafe mode when performing excavation and development of mining underground rooms. An unusually high number of injuries in the technological stages of excavations transport and delivery of raw materials, which are mostly mechanized, indicating a subjective omissions. This indicates that the shock direction in reducing individual violations in mines should be directed towards increasing mechanization phase and improving employees' training.

When it comes to violations of the qualification structure shows that the greatest number of injuries occurred among low skilled and skilled workers, but it is necessary to point out that for unskilled, semi-skilled and skilled workers in proportion to the number of injuries proportionate to the number of employees.

As far as the risk of accident and collective threat to the consistent implementation of the necessary standard precautions when working in conditions of methane occurrence and dangerous coal dust, vulnerability to exogenous Fire and handling of explosives. Consideration of the natural geological conditions and the possibility of a collective threat to its coal can be noted that in the coal deposit, the mine "Soko" there are certain limitations arising from the existence of the phenomenon of discharge and separation of high concentrations of methane and the unresolved system of excavation. These disadvantages require the application of a special operation (intensive informative drilling, application systems ADK, enhanced operational control of gas, ventilation and fire parameters) which are required to be.

A general statement of the mines is a low level of mechanization and outdated technology that provides low-production effects and troubled economy. The share of heavy physical work is important so that the increased possibility of injuring employees. Practically since 1992., working there was not a mechanized širokočelnog digged, and not procured nor machines for mechanized mining pits (harvesters, loading machines, drilling machines), as well as equipment for additional security parts of the mine (anchors, shotcrete and other):

The last 10-odd years are excluded to the extent necessary investigations so that the relatively low level of exploration for the proper direction of exploitation of mining operations in the pits, which was particularly pronounced in 2013.

Due to incomplete and unreliable technical basis for the design came to the deficiencies of design solutions and thus to frequent changes conceptions of the works, which also had an effect on the development of the mine and increase safety and security problems.

4. **CONCLUSION WITH SUGGESTIONS OF TECHNICAL MEASURES**

Underground coal mining by its nature, is the holder of the potential risk of accident individual injury, and if we add to the poor equipment and insufficient training of workers in mines significantly increased risks for employees.

The requirement to reduce the number of employees injuries certainly increase overall safety in underground facilities mines JP PEU, or improve the level of safety and health of employees which requires systematically and consistently implemented and designed the prescribed protection measures, which consist of preventive measures and ongoing

A large number of injuries in the technological stages of excavations transport and delivery of raw materials, which are mostly mechanized, indicating the need to increase labor and technological disciplne. This suggests that in order to reduce individual violations in the mines core activities should be directed towards increasing mechanization phase and improving employees' training.

Based on the research results enabled a comprehensive understanding of patterns, sources, methods and consequences of injury in order to blagovremnog take adequate protection measures or the safety and health of employees in rudnicma JP PEU.

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UDK:622.272:622.283.4(045)=20

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SUPPORT TECHNOLOGY IMPROVEMENT IN LEVEL ROADWAYS ECONOMIC IMPACT AT COAL MINE SOKO - SOKOBANJA

Abstract

Development of level roadways at Soko coal mine is based on drilling and blasting technology, while the supporting of these roadways is based in arched steel support. Applied supporting technologies provides benefits, but it has some shortcomings such as hampered materials supply to the face, hard and risky labour during the installation of the arches, high cost of steel resulting in increased cost of level roadways development in the mine.

Improvement of existing supporting technology can be achieved with introduction of AT rockbolting in combination with arched steel support, which will prevent deformation propagation into the strata around the roadway, resulting in its increased stability. Final part of this article provides economical parameters and assessment of possible introduction of AT rockbolt.

Key words: supporting technology, AT rockbolting, stability, level roadways

1. INTRODUCTION

Room and pillar method of work, with top coal and roof caving and with transversal excavation roadways, is used in the Soko coal mine. Coal mining after opening the deposit begins with making preparations of development and level roadways. These level roadways provide access to production zones, and create conditions for the normal functioning of the transport process of coal, materials supply, ventilation, and other basic or auxiliary stages of the mining process. The stability and reliability of achieving production capacity and exploitation of deposits in general depend on their functional ability. Figure 1 shows a cross section of the coal seam at Soko mine, showing the position of level roadways (EH). Drilling and blasting technology is used for development of level roadways at Soko mine. These roadways are horizontal and are located in the upper part of the coal seam (just below the marl band). They are of circular cross section with a diameter of 3.5 m (Figure 2).

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Circular arched steel support is used with spacing at distance 0.5 to 0.8 m, depending on the state of the coal seam and the manifestation of underground pressures. Gap between embedded arched steel frames is filled with wooden lagging.

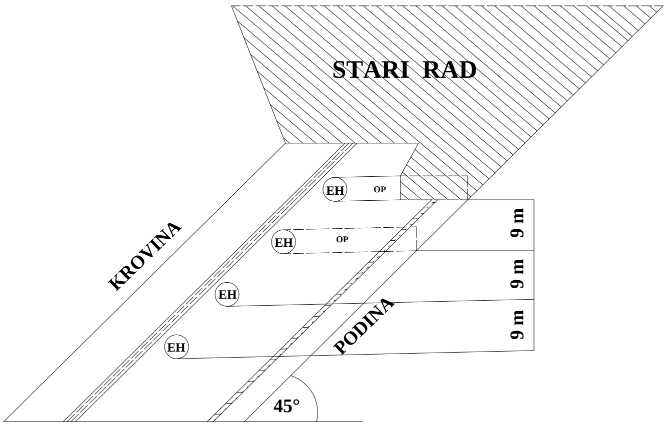


Figure 1: Cross section of coal seam in Soko coal mine

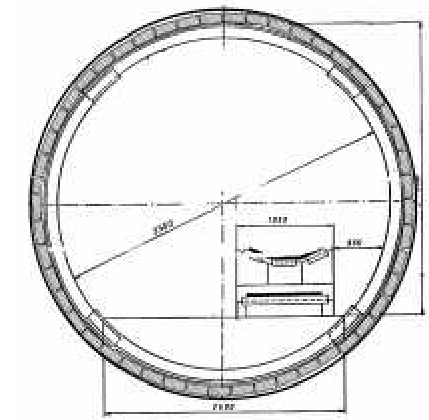


Figure 2: Cross section of layer roadway

Supporting technology with arched steel support is very demanding and technologically obsoleted technological discipline. Disadvantages of application of this technology are:

- difficulties in supplying the steel support to the site (large mass, the manipulation of large dimensions in confined space, complex configuration cableway, work at great depths)
- frequent and costly replacement of deformed steel (reconstruction of level roadway) because of underground pressures
- significant share of the heavy manual labour during the installation of steel support
- high steel prices and
- high unit price per meter of level roadway.

In particular it should be noted that the problems involved in materials supply and reconstruction of level roadways will escalate with increasing depth of the mine.

In order of solving mentioned shortcomings and improving the supporting technology, AT rockbolt support is identified as a modern technology, which application could lead to the substantially improvement of the physical condition of level roadway. AT rockbolt support would provide substantial savings of expensive steel support, achieve greater stability of level roadways and therefore reducing the maintenance of these roadways, a simpler technique of supporting and more humane working conditions for miners. Also, this approach would provide significantly lower cost of roadway development.

2. DESCRIPTION OF AT ROOF SUPPORT

The operation of this type of support is based on the principle of preventing the spread of deformation at massif depth, especially in layered and cracked areas or in layers of coal with parquet structure. Installation of bolt creates a zone of hardened massif around the roadway. Therefore we can say that AT roof support is active support that is it comes into effect before the contour of the underground structure deforms. On the other hand, the steel support is passive support, that is it receives load after deformation of the massif and contours of the room. The environment in which it is contained AT rockbolt support, namely the immediate surroundings of the roadway, can be seen as an environment with modified (enhanced) physical and mechanical characteristics, which is of particular importance since a stress concentration which causes deformation is created in these areas.

The main element of AT roof support is bolt, made of reinforced steel bar. When installing this type of bolts into the drilled hole is placed cartridges with epoxy resin first, wherein the resin represents one component and the other catalyst. A characteristic of these mixtures is that at uniting components comes to its solidification. The anchor during the installation is pushed into the borehole while rotating, wherein the components of the cartridge are split up and leads to their compounding and solidifying. After solidifying the mixture tightening of the nut is done.

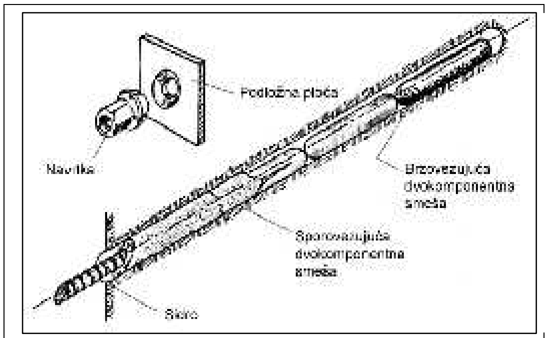


Figure 3: Full column resin bonded rock bolt

Full column bonding and the subsequent tightening of bolts (torque to 200 Nm generates a force in the direction of the axis of the anchor) is crucial to prevent the spread of deformation at depth range.

In most cases the AT bolt is not able to reach the stable high roof part. However, experience has shown that in such situations AT rockbolt support can be applied with great success. The explanation for this lies in the fact that distortion and layering of immediate roof causes displacements in the vertical and horizontal plane, so that the installation of AT anchors in this environment prevents or greatly reduces the displacements, and the subsequent tightening of the anchors generates force along the axis of the anchor causing the same vertical displacement of all the layers around the roadway. To put it simply, installing this type of roof support connects thin layers in a thicker and stronger one (Fig. 4), in which, when considered as beams, thicker layer has better mechanical properties than the sum of these characteristics of thin layers.

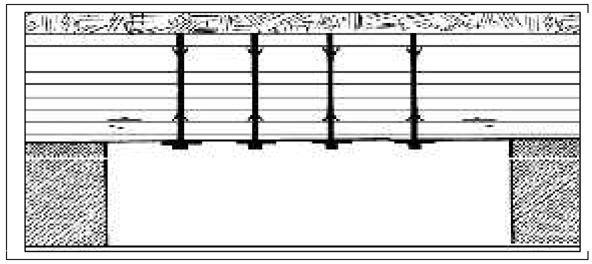
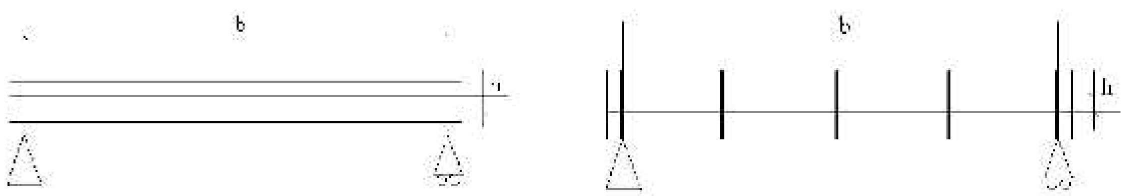


Figure 4: Beam forming by connecting thin layers using AT anchors

Studying the effects of beam forming have shown that this effect is more prominent with decreasing distance between adjacent rows of anchors, with increasing subsequent tightening force, increasing the number of bonded layers in the roof and decreasing the width of the roadway. It was also found that the formed beam has a higher strength parameters than the sum of resisting ones of the individual layers that make up the beam, and the formed beam has a greater rigidity to bending (Figure 5).



a) *b)*

Figure 5: Comparison of connected and not connected beams

- ***not-connected; b) connected***

The ratio of strength parameters of formed beam (W2 / W1) is "n" times larger than the resistant moment of beam whose layers are not connected, while the stiffness ratio (T2 / T1) is higher for "n2" times with beams with bonded layers. In this way it is practically demonstrated that applying the hanging support consisting of bolts with continuous attachment and their subsequent tightening improve the characteristics of the immediate roof layers, so that by the installation of this kind of support can be considered as the reinforcement of the rock mass, since it increases the load capacity of immediate roof layers.

3. TECHNICAL DESCRIPTION OF SUPPORTING BY COMBINED SUPPORT

Supporting of level roadways with combined support, which includes supporting of developed profile of level roadway in the progress by installing the arched steel frames – arch support in the frame spacing of 0.5 -0.8 m. The roof between the two successive steel frames is supported by steel mesh and reinforced by installation of bolts around the perimeter of the room, which closes a cycle in progress. Figure 6 shows the initial installation scheme of AT rockbolts in level roadway with a lagging of steel mesh instead of wood.

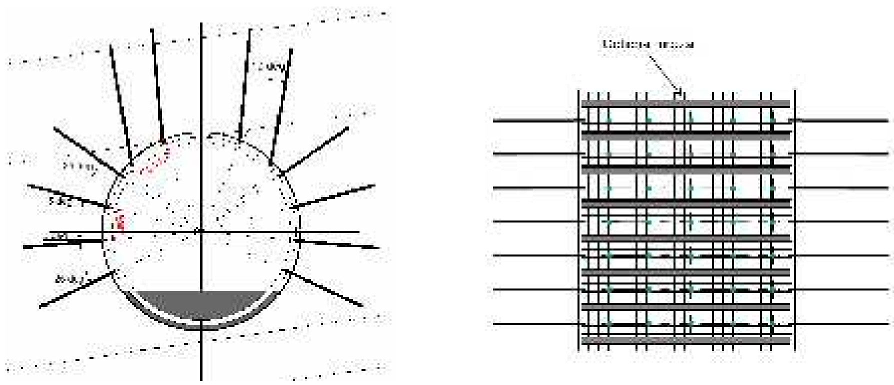


Figure 6: Initial installation scheme of AT roof support with steel mesh

Initial installation scheme of AT roof support in level roadway is provided with a relatively high density of - 1.2 anchors/m2 (typical density of anchors for unstable environment). As the figure shows five anchors length of 2.4 meters will be installed in the roof, and four bolts with length of 1.8 m in each side. Central roof bolt, in the axis of the roadway, should be installed vertically while the other four (two by two) anchors should be installed at an angle of 10O. The distance between the mounting points of the roof bolts should be 0.76 m.

By systematic anchor installation will be enable additional tests, which will indicate the possibility of further improvement of installation schemes with measured data. Advancing the room at certain places (closer to the forefront of the site) are installed measuring devices:

- **sonic extensometers –** for monitoring deformations in the roof and ribs of the roadway,
- **strain-gauged bolts –** for measuring the deformation of the massif above the installed bolts. These measurements confirms the validity of applying the support. Data analysis is done on the computer using a special software, with the possibility of graphical interpretation of axial loads and bending moments of anchors. Figure 7 shows the scheme of installation of strain gauged bolts and Figure 8 test results (graphic interpretation of the anchor axial forces load and bending moments).

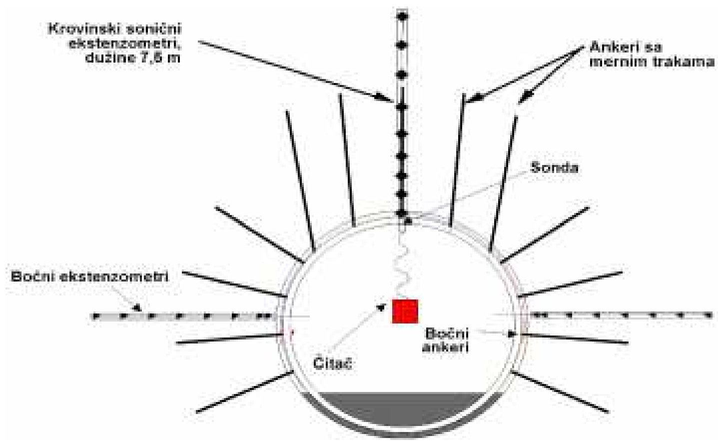
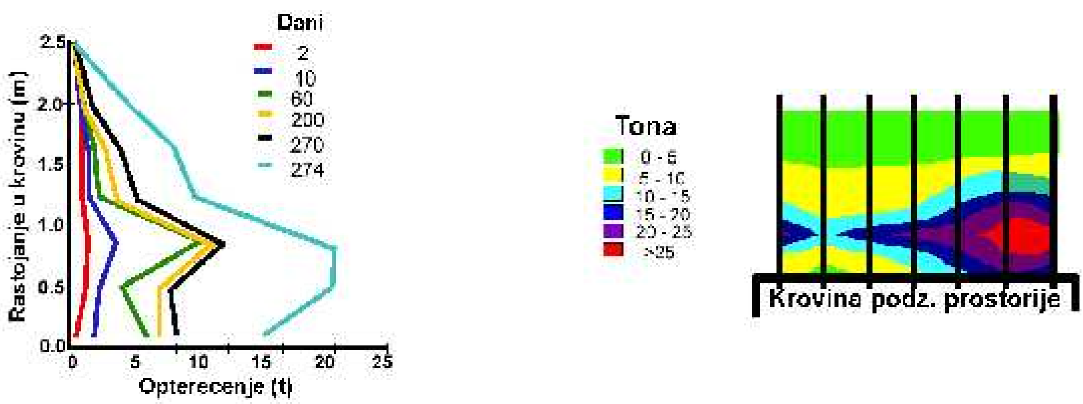


Figure 7: Installation scheme embedding of strain gauged rock bolts in level roadway



a) *b)*

Figure 8: Example of graphical interpretation of the readings from the strain gauged bolts

a) Axial load in the previous period (in days)

b) Bending moment of bolts

- **dual height „tell – tale“ –** to monitor the deformation below (indicator "A") and above the bolting height anchors (indicator "B"). Each indicator is hanged on the anchor which is placed at a certain depth in the borehole. The anchor of which is suspended the upper indicator ("A") is placed 0.15 m below the height of the anchor while the indicator "B" is set at a depth of 5 meters or approximately twice the length of the anchor. The sum of the values of deformation at pointers "A" and "B" is the total deformation under upper anchor "B", i.e. the total deformation along the borehole.

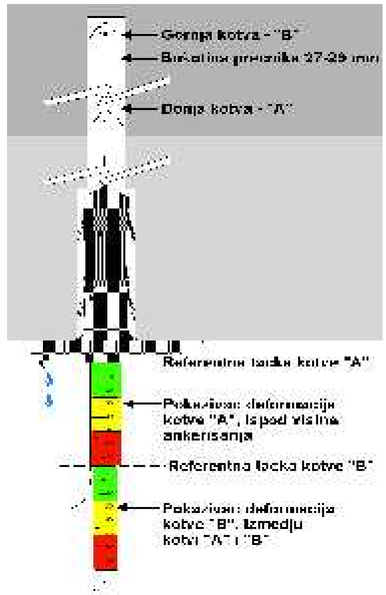


Figure 9: Schematics of dual height „tell – tale“

The aim of the installation of measuring devices is to monitor the deformation and the influence of underground pressures on the support after the development of the level roadways. Based on the results of measurements the optimal scheme of roof support installation of and spacing between steel frames is determined. The best effects this method of support has achieved if the level roadway is developed using the technology of cutting the rock mass (the roadheader).

4. SUPPORTING BY COMBINED SUPPORT ECONOMIC IMPACT

Soko coal mine has an annual production capacity of about 120000-125000 tons of commercial coal. For this level of production it is necessary to develop level roadways with in a total length of about 700 meters, and four ventilation cross-cuts with an overall length of 48 meters. With existing developing technology and the level roadways supporting forward speed is limited to about 50 meters per month. This is a relatively low level of impact caused by the drilling and blasting technology development and conventional way of supporting the roadways with arched steel support. In the context of the technological cycle of level roadways development, most of the time it is spent on the supply and installation of steel support and timber, where these tasks are done with hard physical work. On the other hand, the cost of steel support, which is from imports is the largest component in the prices structure of new roadway, so therefore making negative impact on the economic parameters of the operation of the mine.

Improving support technology of level roadways would provide significant financial effect on the total cost of level roadways. Total cost of level roadways means the sum of cost of development and maintenance costs of the level roadways from development to closure after exploitation. Table 1 shows the comparison of financial indicators of the price of a 1 meter of level roadway supported by arched steel support on frame distance of 0.7 meters, the combined support – arched steel support reinforced with steel mesh and AT anchors on steel frames distance from 0.7 to 1.2 meters.

Table 1: Comparative financial indicators of level roadways development prices

Supporting type	The cost of developing underground rooms (din)			
	Consumables	Salaries	Other	Total
Level roadway development Φ3,5 m supported by arched steel support timber at the axial distance of 0.7m	74.495,00	28.880,00	7.510,00	110.885,00
Level roadway development Φ3,5 m supported by combined support (arched steel and AT rockbolt support) at axial distance of 0,7m 1,0m 1,2m	95.402,00 81.200,00 75.671,00	28.880,00 28.880,00 28.880,00	7.510,00 7.510,00 7.510,00	131.792,00 117.590,00 112.061,00

Previous experience in the Soko coal mine indicate that approximately 25% of the total lengths of roadways are reconstructed every year (about 175 m/y). The level roadways reconstruction consists of replacement of the deformed support and bringing the room to the projected values which are determined by the deformation of the massif occurring due to static and dynamic loads due to excavation. Note that reconstruction of roadways in Soko coal mine begins when the roof supports due to pressures is deformed to such an extent that the cross-section area is about 5.5 m2 (corresponds to arched steel support Φ 2.6 m)

The total price of the level roadway is calculated as the sum of the cost of development and maintenance during its service life. Table 2 shows the total cost of level roadway depending on the method of supporting.

Table 2: The total cost of level roadway development in relation to method of supporting

Supporting type	The total price of the level raodway (din)		
	Costs of production	Maintenance costs	Totally
Level roadway development Φ3,5 m supported by arched steel support timber at the axial distance of 0.7m	77.610.000,00	19.404.000.	97.014.000
Level roadway development Φ3,5 m supported by combined support (arched			

steel and AT rockbolt support) at axial distance of 0,7m 1,0m 1,2m	92.254.400 82.313.000 78.442.700	– – –	92.254.400 82.313.000 78.442.700

5. CONCLUSION

The analysis of Table 2 shows that the application of combined support (arched steel support and AT rockbolt support) in the preparation of level roadways in the Soko coal mine results in substantial savings (in financial terms) in the total cost of making the level roadways after exploitation. Increasing the frames distance progressively increases the level of savings:

- 0.7 m frame distance 4,759,600.00 din.
- 1.0 m frame distance 14,701,000.00 din.
- 1.2 m frame distance 18,571,300.00 din.

However, in addition to the financial effect which is important (it does not matter of what time we are talking), an important role is played by the stability of the level roadway or preservation of the projected profile, which is one of the most important factors for the security and safety of miners. In addition, the making level roadways technology plays important role. This analysis was done for the technology of drilling and blasting works, but if it is released in cutting technology (with roadheader) savings will be much greater than what is shown in this paper.

The authors believe that using the combined support (it is necessary to prove the in situ) will avoid or minimize reconstruction of level roadways in the Soko coal mine and achieve considerable savings (in financial terms) in the technological stage of basic deposit preparation for exploitation.

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