

Nikola Stanić, Saša Stepanović*, Aleksandar Doderović*, Miljan Gomilanović**

DETERMINING THE STRUCTURAL PARAMETERS OF SLOPES AT THE OPEN PIT POTRLICA IN THE ZONE OF SEPARATION DOGANJE

Abstract

Due to the coal mining in the Northwest part of the Open Pit Potrlica, in the zone of separation "Doganje", there were considerable engineering-geological processes that have resulted in deformations - landslides. For continuation of mining, it is necessary to carry out a rehabilitation of endangered zone within which there are the final slopes of the surface facility Separation. Rehabilitation of endangered slopes is intended to secure the facility of Separation, but also enables maximum utilization of coal reserves in the respective zone. Therefore, it is necessary to harmonize the rehabilitation works on the endangered slope in a structural and dynamic sense of the future works on coal mining with maximum use of available reserves. Simultaneously with defining the measures and facilities of rehabilitation the endangered zone, a limitation and determination the quantity of coal were carried out that can be safely and economically mined in the rehabilitated zone. Optimal mining limits are determined in the zone between the sections 8 and 10 on the east side in the zone of Administrative building, and on the west side in the zone of separation "Doganje".

Keywords: coal mining, slope stability, rehabilitation

INTRODUCTION

At the Open Pit "Potrlica", the coal and overburden mining are carried out by discontinuous technology of two parts of the open pit - the Northwest and Central parts. In 2016, there was a physical bonding of these two parts of the open pit, but the mining system is further divided into the Northwest and Central part of the Open Pit Potrlica. [1]

In the Northwest part of the deposit (the site "Cementara") Open Pit Potrlica, near the main coal seam, there is also the first overburden coal seam thickness of 0.05 m (drillhole Bc-3) to 2.0 m (drillholes Bc-36 and B- 99), the average thickness of 0.72 m.

It is separated from the main coal seam by the interlayer waste, thickness of 0.5 m (drillhole B-296) to 3.5 m (drillholes Bc-37 and Bc-38), on average of 2.29 m.

The first coal seam overburden consists of marl (³M2). In general, two levels within the marl overburden can be distinguished in the area of "Cementara", as follows:

1. the level of light gray and yellowish marls, and
2. the level of striped dark brown marls, with a significant content of fossil shell conchs and snails in the laminated surfaces inside the dark-belt zones.

* Mining and Metallurgy Institute Bor – Department Coal Engineering Belgrade,
nikola.stanic@irmbor.co.rs, sasa.stepanovic@irmbor.co.rs, aleksandar.doderovic@irmbor.co.rs,
miljan.gomilanovic@irmbor.co.rs

According to the data of all drillholes drilled in the area of "Cementara", the marl overburden thickness is from 1.5 m to 62.0 m (drillhole Bc-1), and the average thickness is 25.54 m.

The marl overburden zone, closer to the ground surface, consists of decomposed marls at the top significantly clayey and transformed into marly clays.

Excavation is carried out with the prior blasting of overburden and coal, except in the Northwest part of the open pit where, due to the proximity of the town Pljevlja, direct excavation and loading are carried out.

Excavation and loading at the open pit Potrlica - Pljevlja are carried out by discontinuous systems. Transport of overburden consists of continuous and discontinuous parts. Discontinuous part of the transport system consists of a fleet of trucks with the capacity of 100 tons.

Continuous part of the transport system consists of 6 belt conveyor with designed capacity of 2000 m³/h or 3664 t/h.

The excavated coal is transported by the existing truck fleet to the plateau for coal

disposal, except the quantities of 100,000 t annually from the Northwest part of the OP Potrlica which are directly transported from the work site to the plant for coal preparation and separation. The other quantities of coal, with transshipment on the plateau, are further transported to the plant for coal crushing and disposal of the Thermal Power Plant Pljevlja.

STRUCTURE OF THE FINAL SLOPE OF THE OPEN PIT IN THE ZONE FROM SECTION 8 TO SECTION 10

The works at the open pit Potrlica of the Coal Mine Pljevlja are carried out according to the Supplementary Mining Project on Coal Mining at the OP "Potrlica" - Pljevlja for the Period 2015 - 2019 (Mining and Metallurgy Institute Bor, 2015). This project documentation has defined a web and dynamics of overburden excavation and coal mining in the Northwest part of the deposit (the site Cementara). Figure 1 presents a structure of the final slope in a part that is the subject of this paper.

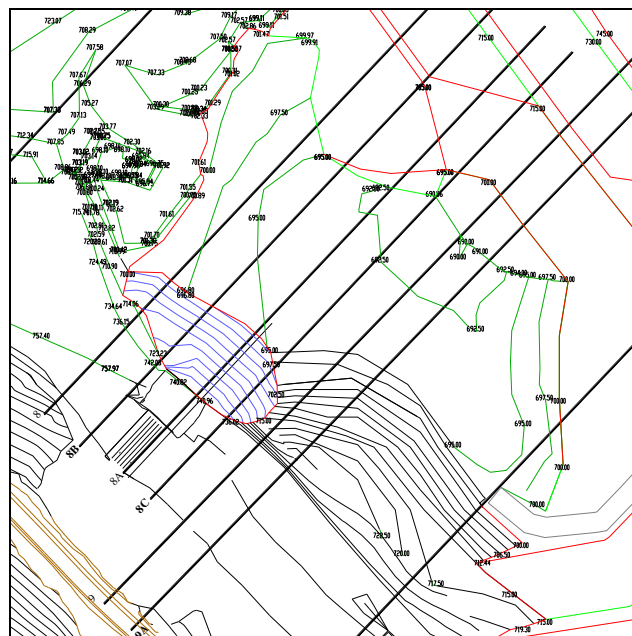


Figure 1 Final slope of the open pit in the zone of Separation facility

Verification the Slope Stability on the Northwest Part of the Open Pit Potrlica in the Zone of Section 8 to Section 10

Verification the eastern slope stability of the open pit at the site Cementara was done on sections 8a, 9 and 9a. [2]

Calculation the safety factor was derived using the software package SLIDE v6.0 of the company ROCSCIENCE.

The stability calculation is done using the program SLIDE in the conditions of limit equilibrium according to the criteria that have been also verified in the most common application. The applied methods in calculation are:





- Bishop,

- Janbu,

- Morgenstern-Price

The parameters of rock materials used in calculation the safety coefficient of slopes at the open pit mine on the eastern side of the site Cementara are given in Table 1. These parameters are adopted on the basis of test results the geomechanical characteristics of the work environment and they are also applied to the site Cementara, and they are verified in the current study and project documentation, as well as geological and thematic engineering-geological elaborates.

Table 1 Parameters of rock material for calculation the safety coefficient

Material	Color	Bulk density (MN/m ³)	Angle of internal friction (°)	Cohesion (MPa)
Coal		0.0135	32	0.21
Clay		0.021	16	0.072
Marls		0.02	39	0.32
Dike		0.016	22	0.034

Engineering - geological sections for calculation the slope stability factors are formed on the basis of reinterpretation the structural characteristics, made on the basis of the results of exploration drillings, specifically carried out for the needs of rehabilitation. As an illustration of derived calculations, the appearance of geomechanical models is given on characteristic sections, with the values of safety factor for one of the used methods. Typical geomechanical sections are shown in Figures 2, 3 and 4.

Structural parameters of designed open pit slopes of the subject zone, first of all, had to fulfill the condition that the minimum allowed safety coefficients should be above the levels allowed by the Regulations

on Technical Standards for the Open Pit Mining of Mineral Deposits ("Official Gazette SFRY", Nos. 4/86 and 62/87) in Table 3 of the Regulations, relating to the stability of individual slopes, system of slopes and final slopes in soft rocks.

During coal mining at the site Cementara and in a part between sections 8-8' and 10-10', it is necessary, due to the existence of objects on the site surface, geological and engineering - geological characteristics of the work environment and constructive characteristics of the work and general slopes, the works shall be carried out with the increased attention, with strict adherence to the prescribed safety measures and to the eastern boundary of the open pit which provides minimum safety factor of 1.1.

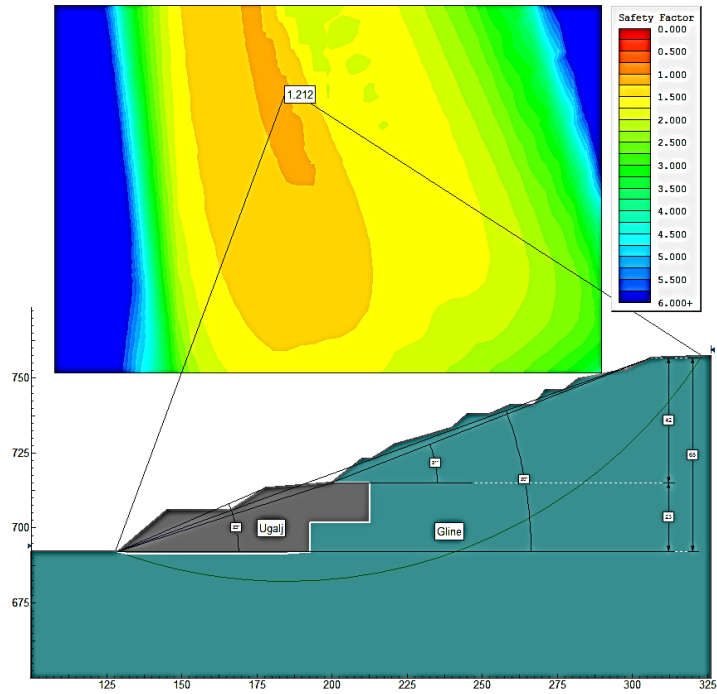


Figure 2 Model and calculated slope stability factor on section 8a

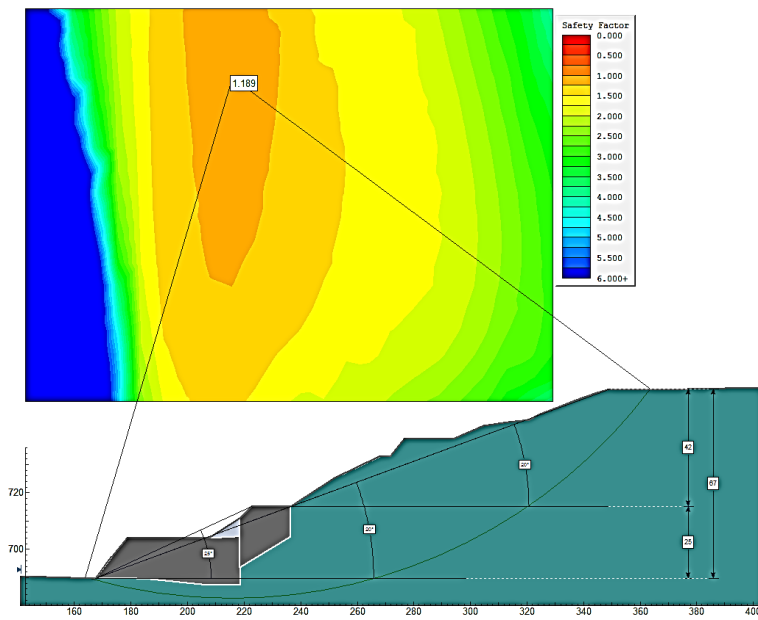


Figure 3 Model and calculated slope stability factor on section 9

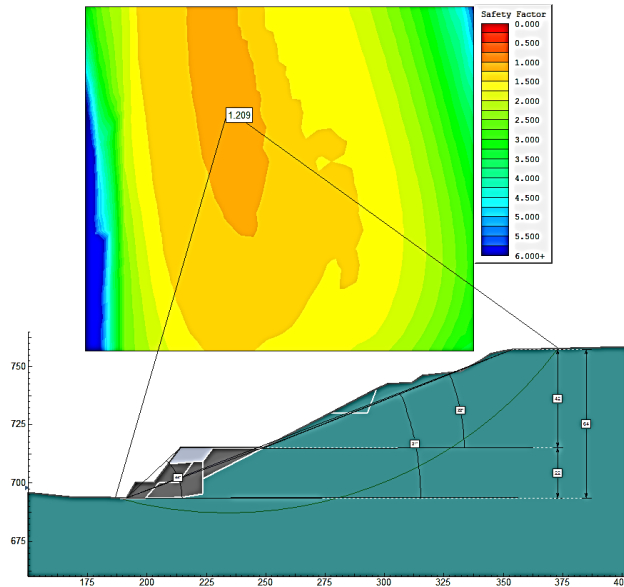


Figure 4 Model and calculated slope stability factor on section 9a

Table 2 Safety factors of slopes on the characteristic sections for the existing condition and deepening work to the coal seam roof

Section	Case	Method		
		Bishop	Janbu	Morgenstern - Price
8a	Existing condition	1.554	1.367	1.557
	Condition with excavation to the coal seam roof (existing)	1.554	1.367	1.557
9	Existing condition	1.889	1.729	1.889
	Condition with excavation to the coal seam roof	1.565	1.409	1.572
9a	Existing condition	2.084	1.865	2.092
	Condition with excavation to the coal seam roof	1.436	1.315	1.434

Table 3 Structural parameters of analyzed slopes and calculated safety factors

Section	Fs min ≈	Partial slope on coal		Partial slope on overburden		General slope		Method		
		Height (m)	Angle (°)	Height (m)	Angle (°)	Height (m)	Angle (°)	Bishop	Janbu	Morgenstern-Price
8a	1,1	23	23.3	42	21.5	65	20	1.212	1.103	1.211
9	1,1	25	24.7	42	20.2	67	20.2	1.189	1.108	1.186
9a	1,1	22	43.7	42	21.8	64	21.3	1.209	1.104	1.208

Verification the Stability of the Western Slope

Verification the stability of the western slope was done successively with the progress of works on stabilization the separation plant (classification plant) Doganje. Verification of stability was carried out on profiles 8a, 9 and 9a. [2]

Calculations were done in the program Phase 2 V8 using the finite element method. The analysis was carried out in phases:

- The first phase with completion the first horizontal beam and excavation of overburden and coal according to a given slope;

- The second phase with completion the second horizontal beam and excavation of overburden and coal according to a given slope;
- The third phase with completion the third horizontal beam and excavation of overburden and coal according to a given slope;
- The fourth phase by lowering of the open pit to the designed depth.

Calculation results are given in the following figures:

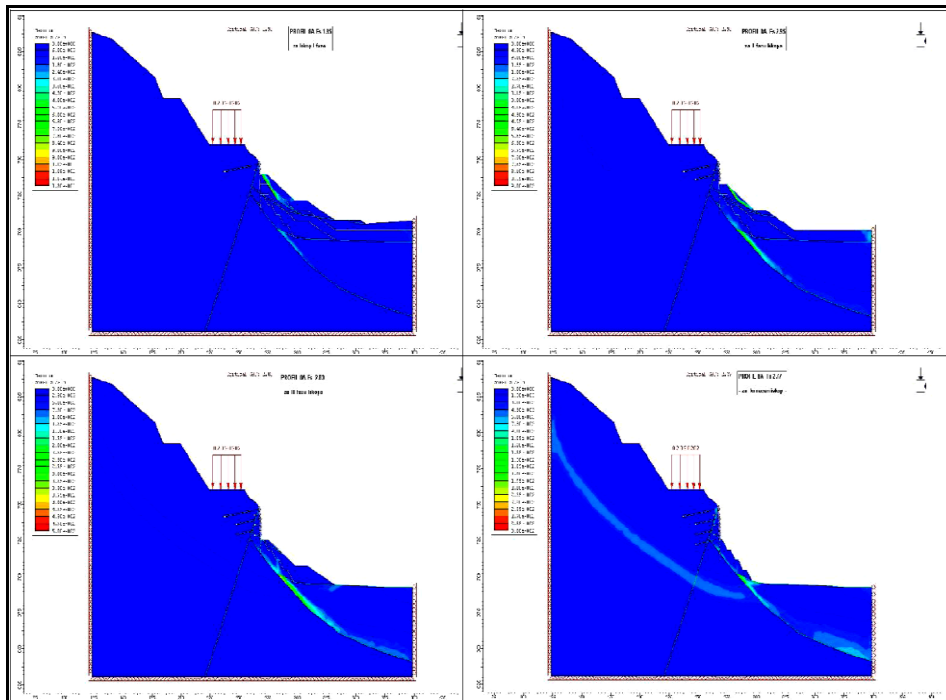


Figure 5 Calculation the slope stability in section 8a (four phases of stabilization the separation plant Doganje)

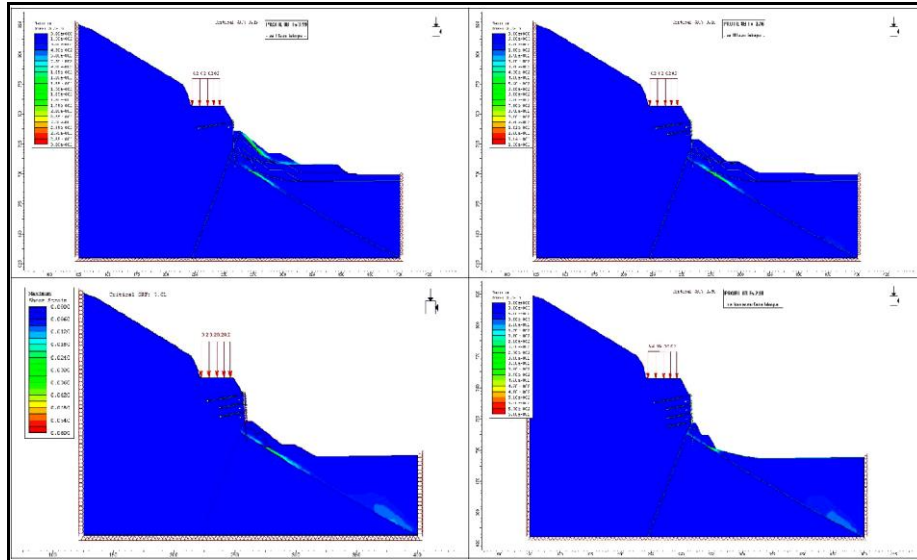


Figure 6 Calculation the slope stability in section 9 (four phases of stabilization the separation plant Doganje)

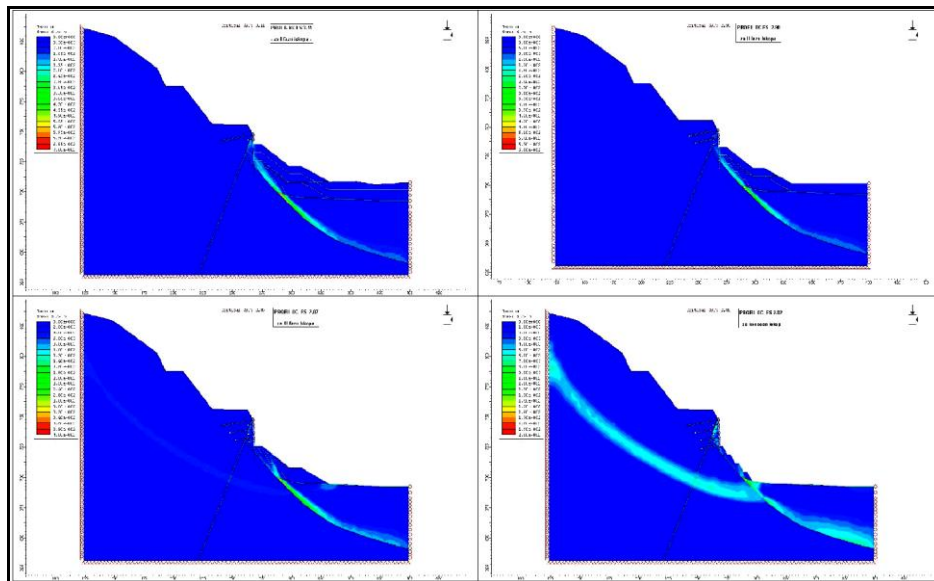


Figure 7 Calculation the slope stability in section 9 (four phases of stabilization the separation plant Doganje)

The values of calculated safety factors for all phases of excavation, in all sec

tions, as shown in Table 4 are satisfactory for stability of temporary slopes.

Table 4 Safety factors for excavation phases

Section	Fs safety factors for excavation phases			
	I phase of excavation	II phase of excavation	III phase of excavation	IV phase of excavation
8a	1.95	2.95	2.83	2.77
9	3.19	3.16	3.01	2.98
9a	3.11	2.98	2.87	2.82

The adopted constructive parameters of slopes of considered part of the open pit at the site Cementara and for which the shown calculation of safety factor was done, i.e. their verification, are the result of the analysis of more variants of technical solutions. The process of defining the rehabilitation measures of the western slope and facilities of the final coal separation of coal and facilities, has implied the analysis of application of several methods and involved the boundary in the plan and depth.

The western slope of the open pit in the zone, where it was necessary to implement the stabilization measures, is characterized by the complex structural-geological and tectonic structure. The deposit conditions affect both the technical-technological solutions of overburden excavation and coal exploitation as well as the efficiency degree of reserves. The same is applied to the eastern final slope in the observed zone of the site Cementara, i.e. it is the environment with complex geological structure and the present engineering-geological processes have resulted to the instability of the slope itself and structures in a function of the open pit, which are located adjacent to the edge of slope.

Due to the presence of these structures out of which the foremost is the Administrative building with wardrobe, the works were carried out on their stabilization. For the safety of work development and importance of structures, a constant monitoring is carried out on the condition of slopes and structures.

Coal mining in maximum possible volume is directly conditioned by the volume

and type of works to stabilize the western slope in the conditions of the eastern slope stability conditions and structures on the site surface with the permanent present requirement to safety of mining works. Therefore, the designed solution represented a compromise between the costs of stabilization the structures of Separation and western final slope and volume of coal reserves to be mined. Also, it was necessary to define the construction parameters of the eastern slope, which will ensure the stability of slope and present structures on one side with reliability degree that requires the importance of these structures, and thereby to maximize the quantities of coal affected the concerned zone.

In all of this, an important factor is a dynamics of works on slope stability, excavation of overburden, coal mining and development of the internal landfill. Shortening the period, in which the space between the eastern and western slope is opened to the floor of excavated coal, will be enabled by the construction of slopes with lower safety factors, i.e. with larger angles of inclination, and consequently the excavation of large coal quantities. The earlier filling the excavated area by disposed overburden and waste, or as quick formation of internal landfill benches, will significantly reduce the risks of instability of slopes and accidents during realization of works. Due to all reasons listed above, the designed slopes took into consideration the necessary dimensions of working plateaus, berms and transport routes of internal transport of overburden and waste.

Calculation the Cubic Volumes of Coal Masses in the Zone of Section 8 to Section 10

Calculation the cubic volumes of coal that remains unexcavated in the zone of western slope of the open pit on the site Cementara was carried out using the method of vertical parallel sections.

Calculation the reserves of solid mineral raw materials by the method of vertical cross-sections is used most often in cases where deposits (ore bodies) of complex shape were explored by works set on vertical sections.

Calculation the coal quantity that will not be excavated on the site Cementara, in the area of the western slope, was made for a part between section 8 and section 10, or slightly wider area affected by works on the stabilization of the structure Separation. It should be borne in mind that coal in the section 8-8' was, for the most part, excavated and the works on coal mining in cross section will not developed.

Table 5 Calculation the coal quantity that could be excavated in the zone od section 8-8' to 10-10' with construction of the eastern slope with $F_s=1.1$

Section	Area (m ²)	Mean area (m ²)	Distance (m)	Volume (m ³)	Weight (t)
8	0	598	19	11,362	15770
8b	1,196	1,146	20	22,910	31799
8a	1,095	1,205	15	18,075	25,088
8c	1,315	1,301	16	20,808	28,882
9	1,286	1,370	15	20,543	28,513
9a	1,453	2,233	67	149,611	207,660
Σ				243,309	337,712

CONCLUSION

Realization of works on coal mining is developed on the site Cementara of the open pit Potrljca by very complex structural-geological and engineering - geological conditions. Complex condition of the working environment and occurrence of the open pit slope instability and structures that are located in the immediate environment, and which are of capital importance for development the mining operations and functioning of the open pit as a whole, have caused the necessity to perform the extensive and expensive works to stabilize the slopes and structures.

These works are in constructive, dynamic and economic terms consistent with the requirements of the technological system of coal mining in the monitored zone, ensuring the safe working conditions for their implementation with maximizing the coal quantities that can be mined. Design solutions of restrictions the open pit, in the zone of section 8 to section 10 of the site Cementara, were created in terms of restrictions the mentioned influential factors, and as a compromise solution conditioned by the necessary investments into structures for stabilization of slopes and structures and profit realized by coal mining.

In further period, it is necessary to give an appropriate technological solution of mining that would allow as soon as possible rapid formation and advancement the internal landfill in the excavated area of the open pit, which would reduce the risk of implementation the mining works and gradually increase the stability of open pit slopes and structures. During the execution of works, the constant monitoring is required for the condition of slopes and structures to the phase when the permanent stability of the open pit slopes is reached by formation the internal landfill.

REFERENCES

- [1] Supplementary Mining Design on Coal Mining at the Open Pit "Potrlica" - Pljevlja for the Period 2015 – 2019 (in Serbian)
- [2] Main Design on Ensuring the Stability of Doganje Separation Structures and Defining the Coal Mining Limit in this Zone (in Serbian)
- [3] Simplified Mining Project for Coal and Overburden Mining from the North-west Part of the Open Pit "Potrlica" (Cementara) (in Serbian)