

TECHNICAL SOLUTION FOR SLOPE STABILIZATION IN THE ZONE OF THE DURUTOVIĆI CEMETERY AND THE NEW ČEHOTINA RIVER BED

Saša Stepanović^{1a}, Nikola Stanić^{1b}, Aleksandar Doderović^{1c},
Miljan Gomilanović^{1d}, Jelena Stefanović^{1e}, Ivan Jelić^{1f}

¹Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, 19210 Bor, Serbia

^{1a}sasa.stepanovic@irmbor.co.rs, <https://orcid.org/0000-0003-3485-201X>,

^{1b}nikola.stanic@irmbor.co.rs, <https://orcid.org/0000-0002-6620-8563>;

^{1c}aleksandar.doderovic@irmbor.co.rs, <https://orcid.org/0000-0003-3665-6784>;

^{1d}miljan.gomilanovic@irmbor.co.rs, <https://orcid.org/0000-0002-1209-7423>;

^{1e}jelena.stankovic@irmbor.co.rs, <https://orcid.org/0000-0001-6418-1814>;

^{1f}ivan.jelic@irmbor.co.rs, <https://orcid.org/0000-0003-4534-0706>

Abstract

During mining works, there are frequent occurrences that indicate the slope instability. The engineering-geological processes leading to these phenomena can be local and temporary or cover a wider area and be present for a long period. During the construction of slope of the Potrlica surface mine in the function of forming a route for the new Čehotina river bed, the cracks appeared on the ground surface and free pieces of rock fell out of the formed slope. These processes were present in the Durutovići cemetery zone, which was the subject of rehabilitation works in the past. This paper describes the procedure of previous analysis of the available results of the older and newer research, history of mining and rehabilitation works in the function of determining the safety coefficient of existing slope and formation the technical stabilization solution if the results of planned monitoring indicate the mass movements outside the permitted limits.

Keywords: open pit, slope stability, rehabilitation, exploration works

1. INTRODUCTION

Currently the open pit Potrlica of the coal mine Pljevlja is the only supplier of coal to the Pljevlja Thermal Power Plant. This is the main reason why the conditions must be ensured for reliable and stable functioning of the open pit in the coming period, the next stage of development the mining works at the Potrlica deposit. The most complex condition for ensuring the further stable development of the surface mine is relocation the existing Čehotina river course along a new route via the internal waste dump. The new Main Mining Design for exploitation of coal, marl and clay as supporting the mineral raw materials at the "Potrlica-Kalušići" open pit until the end of exploitation, as well as the Main Design for relocation the Čehotina River, defined a new river route and mining works were designed in such a way as to ensure the conditions for formation a new river course. On this way, the mining works in the function of formation the open pit and waste dump and hydro-technical and construction works are mutually conditioned and compatible.

During the mining works on the slope formation on the eastern side of the surface mine, in the area of the Durutovići cemetery and the area where the construction of the new Čehotina river bed is planned, cracks appeared on the surface of the ground and blocks of material were separated from the formed slope. These phenomena indicate geotechnical processes that can lead to slope instability. Given that the observed phenomena had a local character in order to reduce the risk of future work on the construction of a new river bed,

Pljevlja Coal Mine requested a solution to rehabilitate the slope in case the general slope instability occurs in the future. The solution would have to ensure the permanent stability of the Durutovići cemetery.

The technical solution of slope stabilization would be applied in the event that during the further performance of mining works and results of geodetic monitoring the formed slope, slope instability and movement of masses outside the permitted limits are established.

2. HISTORY OF ORIGIN AND DESCRIPTION THE ENGINEERING- GEOLOGY PARAMETERS OF THE SLOPE ENVIRONMENT

About 25 years ago, with the works at the open pit Potrica, in a wider area of the Durutovići cemetery, on the eastern slope of the open pit, the cracks were observed on the ground surface, which is a phenomenon associated with the mining operations.

Due to the social importance of the Durutovići cemetery, the Coal mine Pljevlja carried out the extensive rehabilitation works in order to ensure its stability. Figure 1 shows the appearance of the constructed retaining wall.



Figure 1. *Appearance of the retaining wall of the Durutovići cemetery after construction*

Construction of the wall was accompanied by the excavation works, construction of access roads and plateaus. Later, after the wall construction, the previously excavated area was filled with marl, while a fertile layer was applied on the surface and area was reclaimed. Figure 2 shows images of the Durutovići cemetery zone after the retaining wall construction and reclamation



Figure 2. *Satellite images of the Durutovići cemetery zone after the retaining wall construction and reclamation*



Figure 3. *Slope in the cemetery area formed by the new mining operations*

The cemetery is located on a limestone slope, on the surface of which there is a thin layer of humus and clay cover. The higher parts of limestone are altered to a depth of 1 to 2 m. The retaining wall construction was preceded by the explorative geological works and identification of geological structures. From top to bottom, there are: surface clay cover, marl, coal, carbonaceous and marly clay, clays, in some places fatty clays and limestone. The research included the tests of geomechanical parameters of the working environment.

A slope was built in the cemetery area with sooner mining operations and creation the new riverbed route. In addition to the previously mentioned geological environments, there is also the material dumped for the purposes of cultivation in the cemetery area. Figure 3 shows the appearance of the slope and embankment, formed after noticing the cracks on the field surface and local material fallout from the slope

3. ANALYSIS OF THE SLOPE STABILITY AND TECHNICAL SOLUTION OF STABILIZATION

The slope stability analysis was performed on two characteristic sections (GM520 and GM600).

The source of data for the parameters of the working environment as well as the structure of the terrain on the analyzed sections are the results of earlier research, used in the phase of creation the mining and other designs. Based on the available data, the following geological-engineering units were determined: bulk material, marls and marly loamy clays, coal and carbonaceous clays and limestones. The dumped material includes the embankment under the retaining wall, and a disposed material of the internal waste dump is separated as one engineering-geological unit. Geotechnical parameters of this unit are determined by a reverse analysis.

Calculation of the slope stability is performed for the existing condition of the slope, as well as for a design condition after creation a river bed. A stone embankment representing the designed rehabilitation works is on the slope of material towards the cemetery. The calculation was done taking into account the seismicity coefficient and without it. Several variants of the width and height of the stone ramp were made, for heights of 4, 6 and 8 m and widths of 4 and 6 m and an angle of inclination of 35° and 45°. Figures 4 show the calculation result of the GM-600 section in the form of the program output form for the case of a stone embankment of width $S = 4$ m, height $H = 6$ m and inclination angle of the formed slope $\beta = 35^\circ$. This case was adopted as the optimal because it provides stability of the slope greater than the minimum allowed and the smallest volume of work on embankment construction.

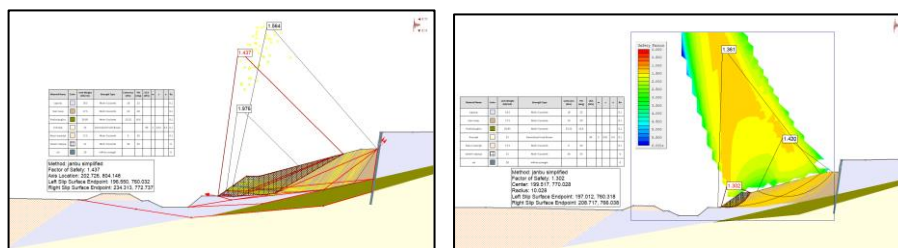


Figure 4. Slope stability on the GM-600 section with dynamic coefficient of safety for the sliding block and circular sliding surface

Table 1. *Calculated slope stability factors at the GM-600 section after excavation the river bed, formation of the slope and construction of the stone embankment*

Factor of safety for the Janbu method	With dynamic load	With static load
Sliding block	1,437	2,019
Circular sliding surface	1,302	1,675

The crushed stone, i.e. limestone, is used for a stone wall formation. The lower part of embankment at a height of 1 m is formed from larger pieces of granulation + 400 mm. The rest of embankment is formed from the broken stone with a granulation of +0 - 400 mm. The contact between the old embankment and stone embankment is covered with geotextile to protect the water permeability. Excavation and planning of previously formed embankment is in the volume of 15000 m³. The estimated amount of crushed stone is 2800 m³. The required area of geotextile is 1800 m².

4. CONCLUSION

It is necessary to analyze in detail all previous activities in the area as well as the results of geological and other research and tests for a technical solution of slope stabilization in order to preserve the stability of the Durutovići cemetery and the new Čehotina river route,

The technical solution itself had to be technically simple to implement, with the minimal costs and to be implemented quickly in the event that the planned geodetic monitoring of the terrain indicates the movements t greater than permitted ones. The construction of an embankment with a width of 4, a height of 6 m and a slope of 35° in the area of the Durutovići cemetery meets these criteria and was adopted as the optimal. In addition to the defined solution, the most important activity in the future period will be a geodetic monitoring.

ACKNOWLEDGEMENTS

This work was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Contract on realization and financing of the scientific research work of the Mining and Metallurgy Institute Bor in 2024, contract number: 451-03-66/2024-03/ 200052.

REFERENCES

- [1] Main Mining Design of Coal, Marl and Clay Like the Accompanying Mineral Resources Exploitation at the Open Pit Potrlica-Kalušići Untill the end of Exploitation, MMI Bor, 2023.
- [2] Elaborate on Detailed Geotechnical Investigations of the Terrain for the Purposes of Developing the Main Design for Relocation of the Čehotina River in the Approximate Direction of its Natural Course Through the Internal Disposal Site of the Exploitation Field of the Coal Mine Pljevlja AD, Geostandard DOO Nikšić, 2023.
- [3] A. Doderović, N. Stanić, M. Gomilanović, S. Stepanović, Mining and Metallurgy Engineering Bor, 1 (2023) 17-26.
- [4] N. Stanić, S. Stepanović, A. Doderović, Ž. Sekulić, M. Gomilanović, 50th International October Conference on Mining and Metallurgy IOC 2018, 30th September - 3rd October 2018, Bor Lake, Serbia, Proceedings, pp. 63-66.
- [5] A. Ateljević, N. Lasica, D. Nikčević, N. Stanić, A. Doderović, Collection of works MINING 2023, Symposium with International Participation SUSTAINABLE DEVELOPMENT IN ENERGY AND MINING, pp. 137-150, Zlatibor, 2023.