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Original Scientific Paper
Mining

Radmilo Rajković, Daniel Kržanović*, Miomir Mikić*, Emina Požega**

REHABILITATION OF THE LANDSLIDE AT THE "LANDFILL 3" IN THE ZONE OF THE ČUKARU PEKI FLOTATION TAILING DUMP**

Abstract

The "Landfill 3" was formed at the location of the flotation tailing dump "Čukaru Peki", where the earthen material, created during the dam construction of the flotation tailing dump was placed. A part of the deposited material and substrate at this landfill has slipped that endangers the local road and "Kusak" stream at the landfill foot. That is why this landslide needs to be rehabilitated.
Keywords: *"Čukaru Peki", landfill, landslide, rehabilitation*

INTRODUCTION

The "Čukaru Peki" copper and gold deposit is located in the central part of East Serbia. The exploitation field of the hydrothermal Cu-Au system "Čukaru Peki" is located about 6 to 8 km in the south of the town of Bor. According to the mine development and transport plan, as well as the selected location for depositing the flotation tailings, in combination with the topographical conditions, the location of the mineral processing plant was selected on the south side related to the deposit, and northeast of the portal of the transport decline. Based on the field research, taking into account technology, economics, construction conditions, environmental protection and other aspects, the flotation tailing dump is located in the east of the processing plant, in a natural valley 4 km away from the flotation plant.

The earthen material is placed on the "Landfill 3" as a product of ground excavation for the purpose of a dam construction for the flotation tailing dump. With the formation of this landfill, in 2021, there was a soil breach on the slope on which the landfill is located, what caused sliding of the clay substrate and deposited material, Figure 1. The moving material interrupted the local road and flow of the nearby "Kusak" stream at the bottom slopes and formed a smaller accumulation.

The cause of landslide activation is the unfavorable geometry of landfill and overloading of the base on which it rests, which caused the ground to break. The slide has covered an area with approximately size of 190 x 260 m.

As a result of pressure of the activated technogenic material and deluvial clays on the lower part of research area affected by the slide, a zone of pronounced surface deformations appears, as a result of large lateral pressures. Deformations appear in the form of accumulation of material and cracks

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on the ground, which completely changed its natural geometry. The zone is developed in the middle of deluvial clays covered with humus and must be subjected to the rehabilitation measures.

The design solution is to achieve the permanent stability of endangered slope changing the geometry, and to break through a new route of the riverbed to dry out the artificially created dam.

Figure 1 *Landslide on the "Landfill 3*"

GEOTECHNICAL RESEARCH

The purpose of geotechnical research is to provide data on the spatial distribution and more important physical-mechanical parameters of all engineering geological members that participate in the construction of this space. Based on these data, with the use of adequate software, it will be possible to find out whether the designed works contribute to the stability, as well as to what extent they can be carried out, so that the stability is not threatened.

A total of eight exploratory drill holes were drilled, the accompanying field works were carried out and an optimal number of samples were taken for the laboratory geomechanical tests.

As part of field research and creation of geological-geotechnical documentation, the following field investigations were carried out:

- Engineering geological mapping of the field
- Exploratory drilling
- Standard penetration tests Engineering geological mapping of the drillhole cores
- Taking samples for the laboratory geomechanical tests
- Laboratory geomechanical tests

The following engineering geological media were identified on the investigated field:

- Medium 1 – Colluvium
- Medium 2 – Technogenic material
- Medium 3 – Deluvial clays
- Medium 4 – Clay siltstones, claystones and sandstones.

Seven geotechnical profiles were defined on the site. Calculation parameters were determined for stability calculation for each working medium, as well as the level of underground water on profiles [1]. The values of calculation parameters for stability calculation are shown in Table 1, the characteristic geotechnical profile is shown in Figure 2.

It is assumed that the thickness of the activated material in the central part is up to 23 m. By mapping the field, a frontal scar visible along its entire length was observed, with a jump of an average of 2 m, with a clearly visible plane along which the movement occurred. The deposited material and part of deluvial clays were affected by sliding.

Table 1 *Values of calculation parameters for stability calculations*

Work medium	Cohesion, kN/m^2	Angle of internal friction, °	Density, kN/m^3
Medium 1 – Colluvium	16	11	18
Medium 2 – Technogenic material	17	12	18
Medium 3 – Deluvial clays	22	20	19.2
Medium 4 – Clay siltstones, clays and sandstones	155	20	19.5

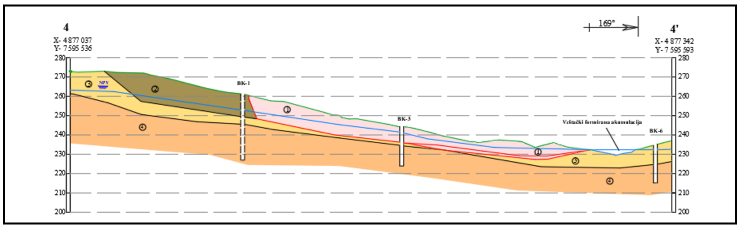

Figure 2 *Characteristic geotechnical profile*

Based on the geotechnical profiles, a 3D model [10-13] of the field and landfill was made in the Gems program, Figures 3 and 4.

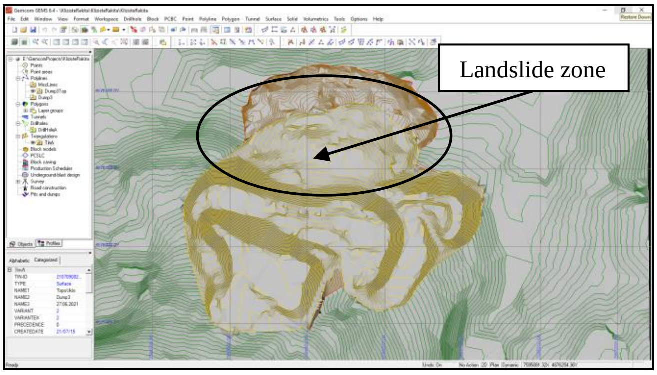

Figure 3 *2D view of the field and landfill model*

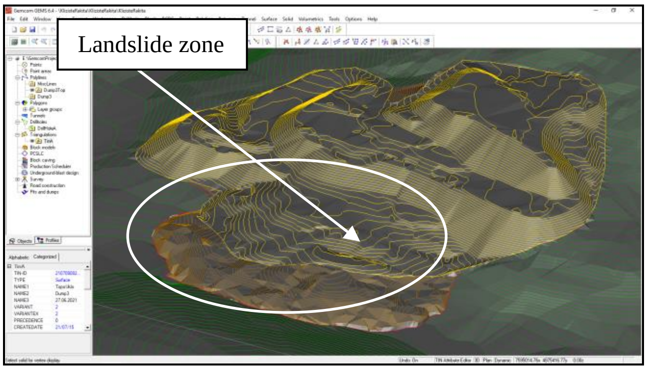

Figure 4 *2D view of the field and landfill model*

A stability calculation was performed on six geotechnical profiles [2]. Figure 5 shows the output interface of the Slide program in which the stability calculation of the existing state was made [4-9]

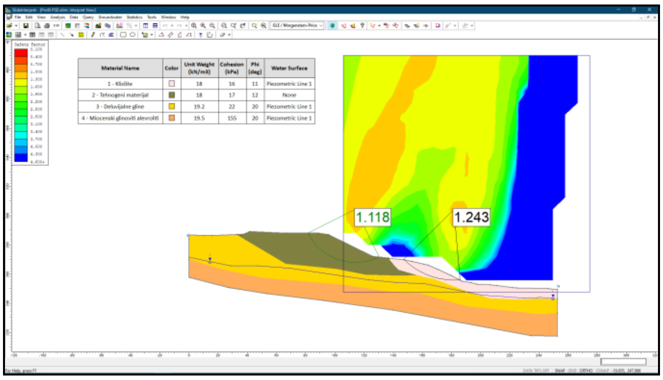

Figure 5 *Calculation the existing landfill state stability in the Slide program*

Analyzing the calculation results of the existing state stability of the landfill, the areas were determined where the safety coefficient is below the legal minimum [3]. The values of safety coefficients of the existing state confirm that rehabilitation of certain parts of the landfill is required. Figure 6 shows the areas of "Landfill 3" that require rehabilitation.

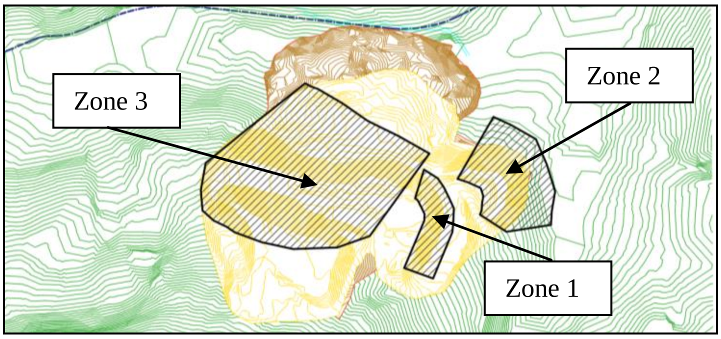

Figure 6 *Rehabilitation areas of the "Landfill 3"*

LANDSLIDE REHABILITATION

Rehabilitation of the landfill critical areas will be carried out by transferring the dumped material from higher elevations towards the base of the landfill, whereby the slope angles will be softened as much as is necessary to satisfy the legal minimum for the stability condition [3].

The material transferred to the foot of the landfill is ballast, which has a positive effect on stability. Work on transferring the deposited material from higher elevations towards the base of the landfill will be done with bulldozers.

The protection of the landfill from water from the catchment areas from which it gravitates towards it during atmospheric precipitation will be carried out by the construction of channels.

Analyzing the slope angles that meet the legal minimum from the aspect of stability, the construction of a 3D model [10-13] of the landfill after rehabilitation was carried out, Figures 7 - 9.

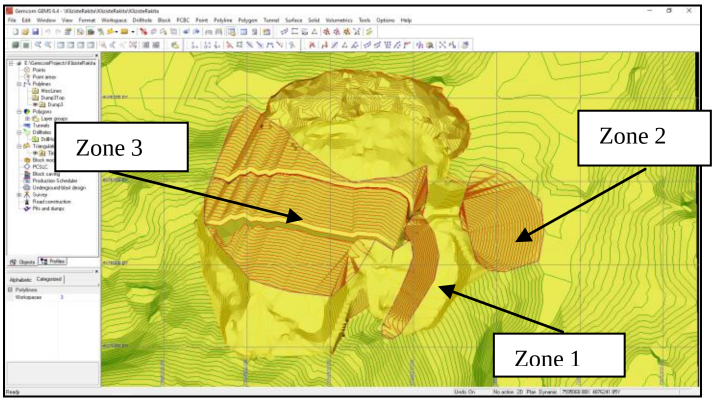

Figure 7 *2D view of the field and landfill model after rehabilitation*

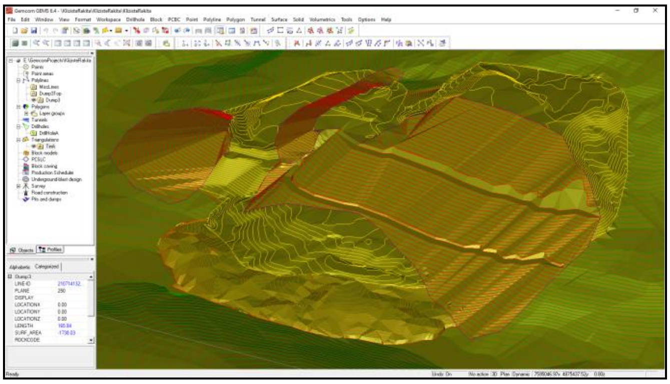

Figure 8 *3D model of the rehabilitated landfill - view from the northwest*

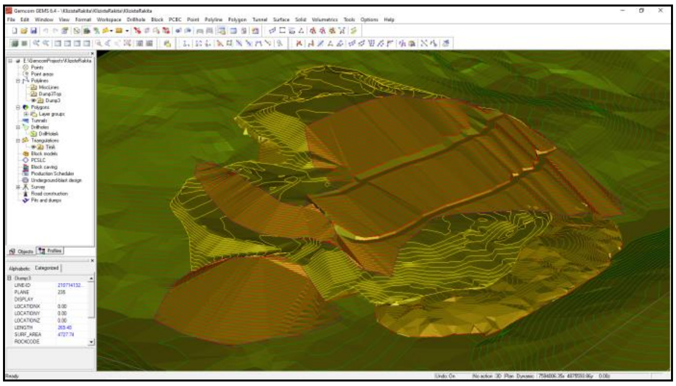

Figure 9 *3D model of the rehabilitated landfill - view from the northeast*

The general angle of slope of the rehabilitated zone 1 is 24°. The general slope angle of the rehabilitated zone 2 is 18°. The general angle of slope of the rehabilitated zone 3 is 14°.

In order to protect the local road whose route passes under rehabilitation zone 3, two bench levels will be built at the levels k+267 m and k+252 m, Figures 7 - 9.

In order to protect the landfill from water from the catchment areas from which it gravitates during atmospheric precipitation, the construction of two channels with sedimentation tanks for settling the solid particles before discharge into natural watercourses is planned: the first channel from the western side of the landfill and the second channel from the southern side of the landfill, Figure 10. Water from both channels, they are taken to a sedimentation tank, from where, after solid particles have settled, they are discharged into the "Kusak" stream.

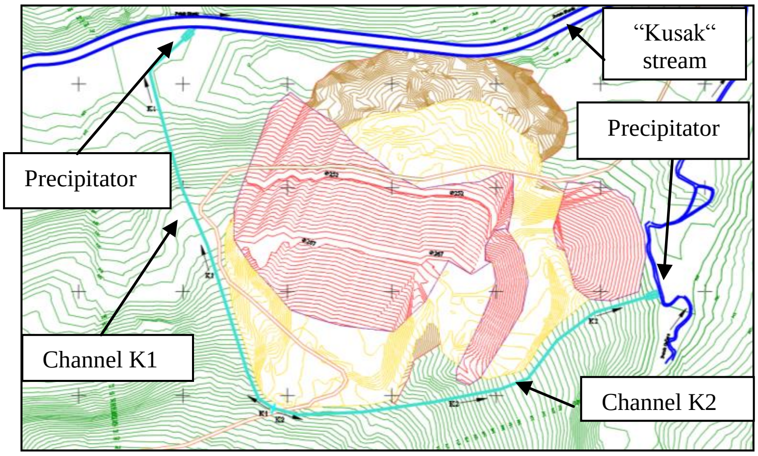

Figure 10 Location of the drainage channel

The stability calculation of the landfill after rehabilitation was done on the same geotechnical profiles and with the same calculation parameters, used to calculate the existing state stability of the landfill [2].

Figure 11 shows the output interface of the Slide program in which the stability calculation of the rehabilitated state was performed [4-9].

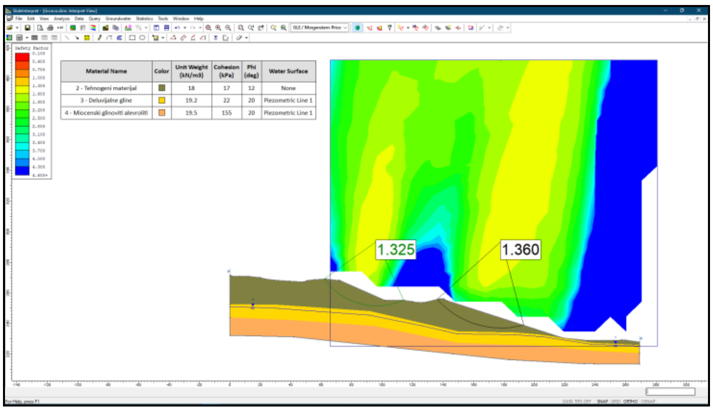

Figure 11 *Stability calculation of the rehabilitated landfill in the Slide program*

Analyzing the calculation results of the landfill stability after rehabilitation, the conclusion is that the legal minimum value of the stability coefficient of F_s = 1.30 for soft rocks on the landfill is met [3].

CONCLUSION

In order to ensure the "Landfill 3" stability, i.e., to rehabilitate the consequences of landslides on the landfill, a part of the deposited masses must be removed from the higher parts of the landfill. Before defining the remediation concept and scope of work, the geotechnical tests of the landfill base and deposited material were carried out in order to determine the stability parameters, structure of base and areas of the landfill to be rehabilitated.

In order to keep the costs of removing these masses as minimal as possible, these masses are not transported outside the location of the "Landfill 3" but are moved to its lower parts. These amounts constitute an additional ballast in the lower parts of the landfill, which has a positive effect on stability.

The designed solution for the landslide rehabilitation ensures the permanent stability of the landfill in accordance with legal regulations.

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