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Radmilo Rajković, Daniel Kržanović*, Miomir Mikić*, Milenko Jovanović**

STABILITY OF THE ASH AND SLAG LANDFILL "MALJEVAC" – PLJEVLJA FOR OVERTOP TO THE PEAK ELEVATION K+832 m**

Abstract

The existing landfill at the site "Maljevac" is still active and should provide the additional space for ash and slag disposal in the following period. For these purposes, the stability analysis of the existing landfill condition, as well as the stability calculation for overtop the landfill to the peak elevation K +832 m were carried out. The stability by analytical profiles was calculated by the licensed SLIDE v6.0 software.

Keywords: *ash and slag landfill "Maljevac" – Pljevlja, stability analysis and calculation, software SLIDE v6.0.*

1 INTRODUCTION

In order to provide the sufficient space for ash and slag disposal that occur as a by-product of opreation the Thermal Power Plant Pljevlja, a dam "Maljevac" was built in 1982 in the bed of Paleški stream, at a distance of about 7 km from Pljevlja. The ash and slag landfill for the Thermal Power Plant Pljevlja was formed by the construction of the "Maljevac" earth dam. In the first phase, a basic dam was constructed with the crest peak elevation of 790.5 m (height 27.5), and in the second phase the dikes - stairs were successively developed to the peak elevation of 813.2 m. Further elevation of dike, which downstream limits the cassette, was developed to the peak elevation K+826 m. The space of the active cassette II is bordered by a dike of an approximate height of about K+832 m, what also represents the final peak elevation of ash and slag disposal at the Maljevac landfill in all analyzed variants.

The transport system of slag and ash from the thermal power plant is solved by a hydraulic means, wherein the mixture of water and ash is led by the pipeline to the landfill where the ash is precipitated. Through the overflow structure, water is taken from the surface of the landfill, i.e. the horizontal precipitation channel, gravitationally to the excavator station, and in this a closed system of recirculation the technological water is formed at the landfill. Below the landfill there is a reinforced concrete collector, a wall thickness of 60 cm, and water of the Paleški stream are led through the channel. The collector consists of the main and secondary one. The length of the

* *Mining and Metallurgy Institute Bor, radmilo.rajkovic@irmbor.co.rs*
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main collector is, after extension during the implementation of the project of stabilization the dam "Maljevac", 1460 m and the secondary is 600 m.

In 2014, stabilization of the dam "Maljevac" was carried out by construction a stabilizing ballast. The works have provided the set conditions of static and dynamic stability. The existing landfill at the site "Maljevac" is still active and it needs to cover the disposal of ash and slag from the TPP until the beginning of opening a landfill on a new location.

STARTING PARAMETERS FOR STABILITY CALCULATION

In 2015, geotechnical "in situ" and laboratory measurements were carried out for the needs of overtop and analyzing the stability of ash and slag dump "Maljevac" - Pljevlja to the peak elevation of 832 m, and all previous research, carried out at this site, were systematized [1].

Excavation of the exploratory pits was performed on the profiles between the exploratory drill holes in a part of the area where there is a small overhead of dike on the natural one for taking the large disturbed samples of disposed ash and slag. Mapping of all pits was carried out in parallel with the excavation, monitoring of the state in excavation and inspection of sampled material.

In addition to the exploratory pits, the exploration drillings were carried out. By performing the exploration drilling, the geological structure on the vertical profile of site was defined, the data on hydrogeological and physical-mechanical properties of soil were collected, the representative soil samples for laboratory tests were taken, the water level was measured in drill holes after their completion, the SPT test was carried out at certain depths and the water-penetration was tested using the filling method.

Calculation parameters, used in the stability calculation at the Maljevac site, are given in Table 1.

Table 1 *Calculation parameters for stability calculation of the landfill "Maljevac"*

Working environment	Cohesion, kN/m^2	Internal friction angle,°	Bulk density, kN/m^3
Site in the ground	7	18	20.0
Disposed ash and slag	0	29	17.5
Dam	5	20	25.0
Waterproof layer in the ground of overtop	5	20	25.0
Waterproof layer and reclamation layer over	5	20	25.0
Stone material in ballast	0	35	19.0

The water level - piezometric line is defined on the basis of NPV drill holes, made at the site. The liquid phase of ash and slag in the landfill is defined by the pore water coefficient of 0.9.

The stability calculation was done by the licensed SLIDE v6.0 program of the company Rocscience, Figures 1 and 2. By the SLIDE program, the stability calculation is done in the conditions of limit equilibrium. The calculation was made using the Janb method that gives the lowest values of stability coefficient in relation to the other methods that can be used (Morgenstern-Price, Bishop, ...) [4-11].

The stability calculation was made in the static and dynamic conditions for the seismic coefficient of the Maljevac region of the return period for 200 years from 0.1.

The stability criterion was adopted in accordance with the prescribed technical conditions for designing the earth dams and hydrotechnical dikes - SRPS U.C5.020 [7], which for the dams above 15 m high is minimum Fs = 1.50 and for dams with high less than 15 m is minimum Fs = 1.30 in case of constant static load, or Fs = 1.00 in case of occasional dynamic load for earthquake occurrence.

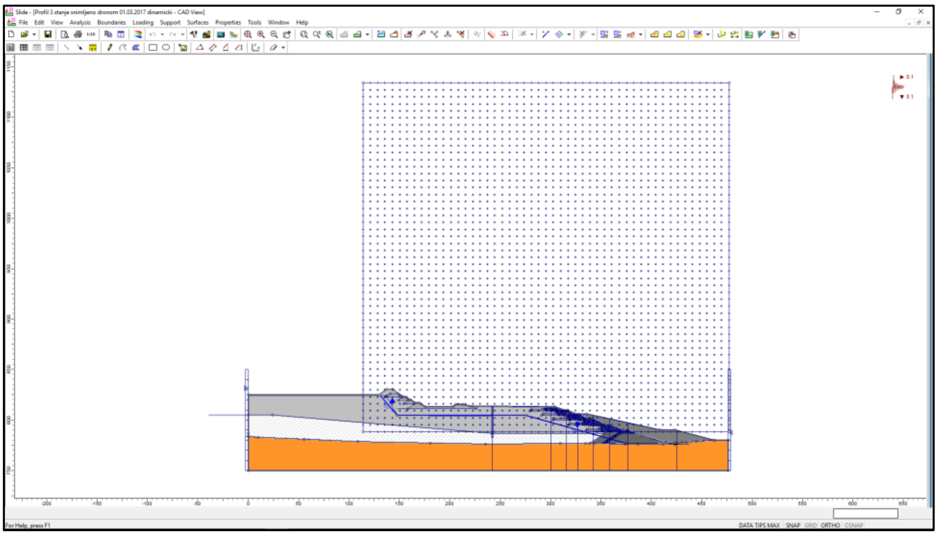

Figure 1 *Operating interface of the software Slide*

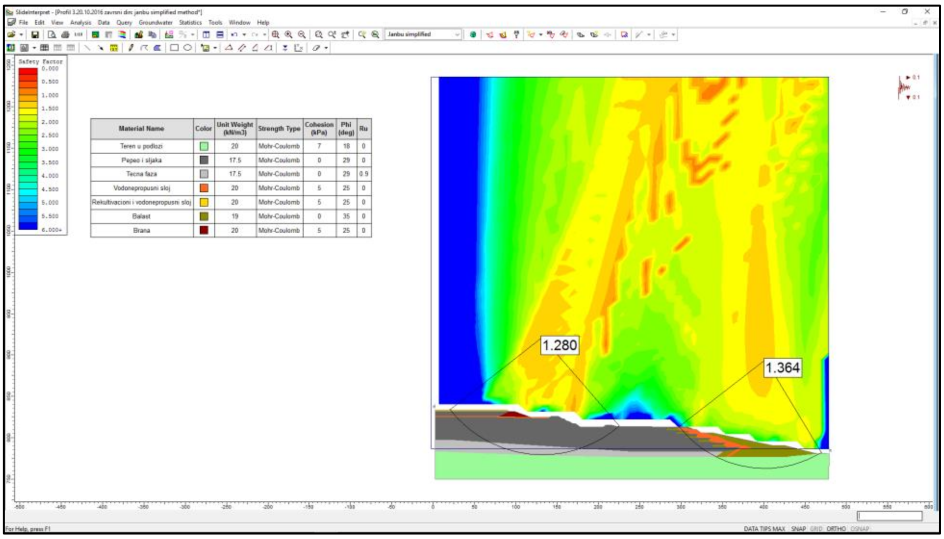

Figure 2 *Output interface of the software Slide*

STABILITY ANALYSIS OF THE CURRENT CONDITION OF THE LANDFILL

Stability analysis of the current condition of the landfill "Maljevac" was done on the profiles I-I' to IX-IX', shown in Figure 3. The profiles I-I' - III-III' are perpendicular to the main dam of the landfill. The profile IV-IV' is perpendicular to the slopes of the existing cassette I and towards the future cassette III. The profiles V-V' to VII-VII' are perpendicular to the slopes of the existing cassette II. The profiles VIII-VIII' and IX-IX' are perpendicular to the slopes of the cassette I [2, 3].

The obtained stability coefficients according to the analytical profiles of the current condition of the landfill "Maljevac" are shown in Table 2.

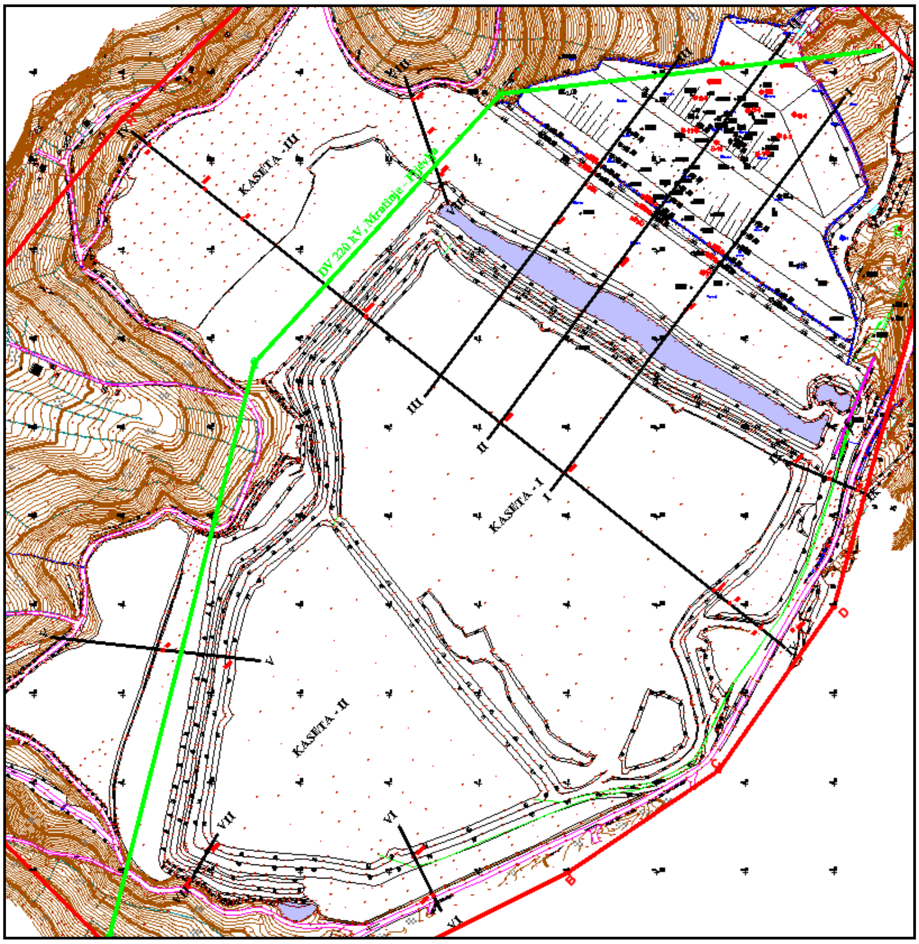

Figure 3 *Position of the analyzed stability profiles for the current condition of the landfill "Maljevac"*

Table 2 *Stability coefficient of the current conditions of the landfill "Maljevac" by the Janbu method*

Profile	F static	F dynamically
I – I'	1.591	1.287
II – II'	1.520	0.940
III – III'	1.537	1.229
IV – IV'	1.511	1.024
V – V'	1.238	1.021
VI – VI'	1.745	1.428
VII – VII'	1.672	1.367
VIII – VIII'	1.815	1.407
IX – IX'	1.549	1.177

By comparison the obtained stability coefficients with the coefficients prescribed by the technical conditions for designing the earth dams and hydrotechnical dikes - SRPS U.C5.020, it can be established that the critical part is the central part of the landfill "Maljevac" in the area of the main dam even in the case of dynamic loads due to the occurrence of earthquakes.

The main cause of insufficient stability in the central part of the main dam of the landfill "Maljevac" is a high level of liquid phase of ash and slag in this area, Figure 4.

As the overtop of the landfill is envisaged, it is necessary to take the remedial measures to ensure the required stability.

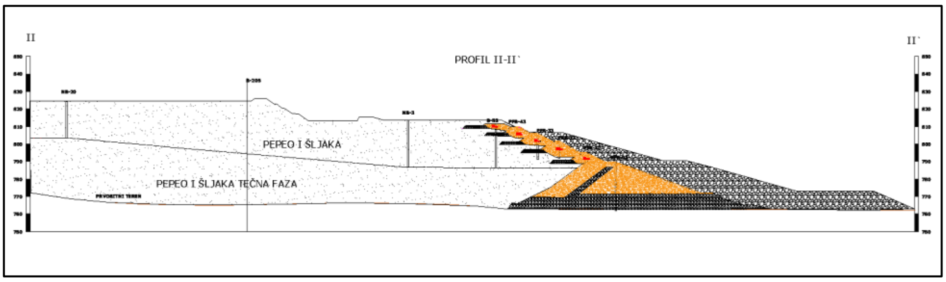

Figure 4 *Geological profile II – II' of the current condition of the landfill*

LANDFILL STABILITY TO K+832 m

As before ash and slag disposal in the cassettes in base, a waterproof layer is made, and after finishing the ash and slag disposal a waterproof layer is also placed on the cassette surface for the final condition of the landfill, the piezometric water level is below the waterproof layer in the base, Figure 5. The piezometric water level for the final condition of the landfill is lower than the initial condition, what is the result of application the following rehabilitation measures [3]:

1. Covering the cassette I with a layer of low-permeable clay, thickness 1 m;
2. Covering the 5^{th} step of the main dam with a clay layer of 1m;
3. Construction of a new horizontal precipitator with clay and HDPE foil;
4. Closure of the existing precipitator and covering a clay layer of 1m;
5. Construction of drainage wells on the 5^{th} step of the main dam for lowering the water level in the landfill;
6. Upon termination of exploitation of the cassette II, closure of cassette with a clay layer of 1m and 1m of soil for rehabilitation of the cassette.

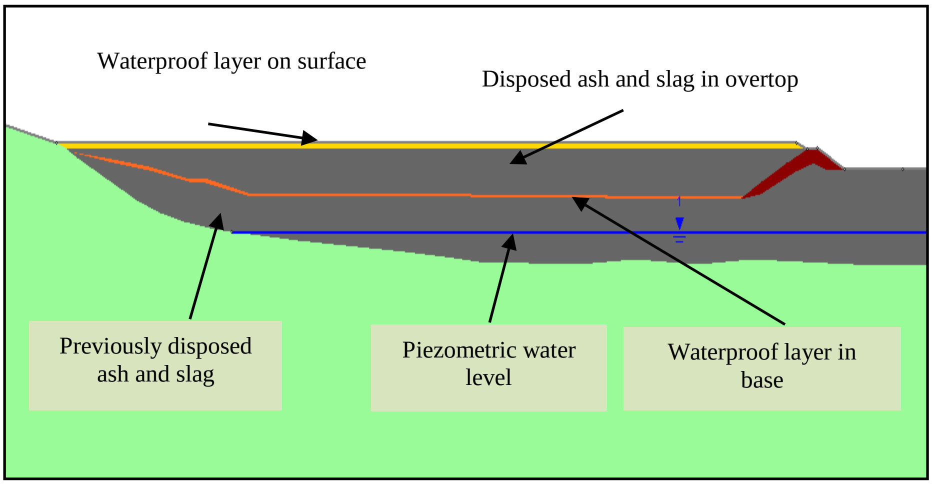

Figure 5 *Representative profile of the landfill after use of the rehabilitation measures*

Disposal of ash and slag in the future period, after filling the cassette II will be done in a unique cassette III and IV. The last phase is disposal in the cassette I. In order to prevent infiltration of water into the natural soil, a protection of base is predicted with a waterproof material - clay, a layer thickness of 1.0 m. This protection is made before the start of disposal in the unique cassette III and IV and cassette I. This prevents further contamination of soil and groundwater as well as the stability improvement of the existing and future dikes. This concept provides the completely hydraulically independent fields. The Field I is bordered from all sides by the waterproof material, both on the bottom and on the peripheral dikes that are also made of clay.

At the existing landfill in Maljevac, there is a functional system for accepting and recycling of overflow-technological water. This system consists of the concrete overflow chutes inside the active cassettes, which through the plastic pipelines drain water from the landfill to the entrance into the horizontal precipitation channel, in which the secondary precipitation of the finest ash particles is carried out. At the exit from the precipitation channel on the right side of the dam, there is an overflow structure with two overflow holes. This overflow structure will undergo small changes in the form of lowering the overflow edge so that the drainage water can be evacuated with this system. The horizontal precipitation channel will be moved down by the fifth step. A new precipitation channel will be coated with a layer of clay, thickness of 1.0 m, over which the foil is placed, thickness of 2.5. This is due to the prevention of ground water penetration into the dam body, thus achieving greater stability of the structure.

The existing precipitation channel is planned to be closed and sealed with poorly waterproof clay material, and a new precipitation channel is going to be built next to it in accordance with the modern technical and ecological solutions. This is done in order to create the waterproof conditions in a channel for overflow and drainage from the landfill. The existing channel is built in ash, and therefore in a waterproof material. The process water from the precipitation channel pass freely and drain into the lower layers of the dam, so that they significantly influence the level of groundwater in the dam body, which directly affects the stability coefficient of the entire slope of the landfill, which is in this part of the dam under the legal minimum. The new channel will be coated with the waterproof material. Waterproofing is provided with a layer of clay material, thickness of 1.0 m, and the HDPE foil, thickness of 2.5 mm.

In order to achieve the necessary stability coefficient of the landfill, it is necessary to continually drain the water from the body of the landfill. Technological water is partly discharged as the overflow water while one part is submerged, infiltrating into the body of the landfill. In order to achieve the necessary stability coefficient of the dike, the groundwater must be maintained at the appropriate level. The most efficient way to regulate the level of groundwater is the construction of an appropriate drainage system for drainage of water.

The drainage system increases the safety coefficient of the main dam of the landfill. By reduction the level of ground water in the body of the main dam, the efficient drainage system also achieves an increase in the useful volume for ash and slag disposal in the designated area, resulting in faster water drainage and, consequently, drying of deposited material.

In this case, the drainage system is laid on an already prepared base of waterproof material. The base is made towards the drainage pipes. By overtop of the landfill, the drainage pipes are installed on the floors of the dump overtop.

Upon completion of disposal, each cassette will be closed in accordance with the Rulebook on the closer characteristics of the site, conditions of construction, sanitary-technical conditions, operation method and closure of landfills. Construction of a waterproof layer of clay of 1m and 1m of soil for cassette rehabilitation was proposed.

Stability calculation of the cassette dike is made for profiles 8-11 and 14-20, for the final landfill, Figure 6, as well as for the profiles of the main dam I-I' to III-III' for the final condition of the landfill.

The obtained stability coefficients according to the analyzing profiles of the final condition of the landfill "Maljevac" are shown in Table 3.

By comparison of the obtained stability coefficients to the coefficients prescribed by the technical conditions for designing the earth dams and hydrotechnical dikes - SRPS U.C5.020, it can be established that by all analyzing profiles, the coefficients of stability are in the prescribed values.

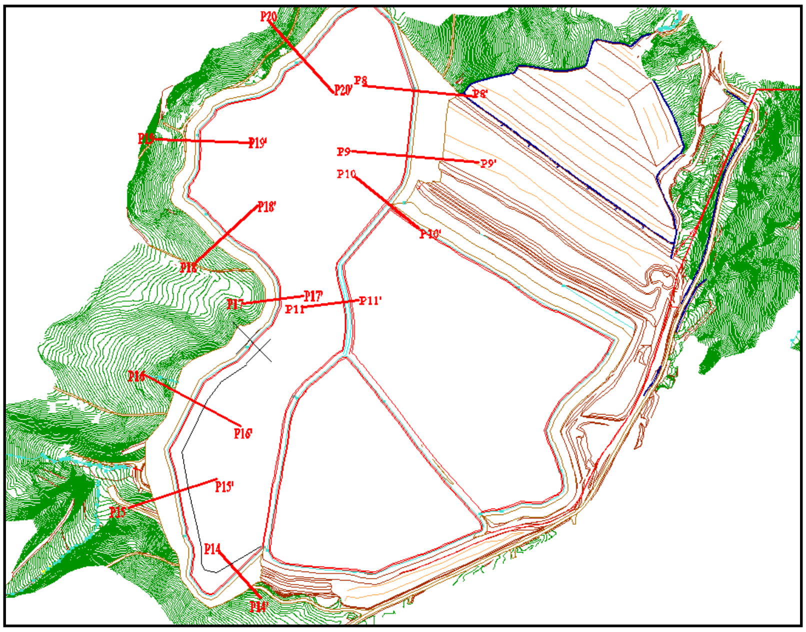

Figure 6 *Position of the analyzing stability profiles for the final conditions of the landfill "Maljevac"*

Table 3 *Stability coefficient of the final condition of the landfill "Maljevac" by the Janbu method*

Profile	F static	F dynamically
8 – 8'	1.923	1.315
9 – 9'	3.081	2.099
10 – 10'	1.504	1.195
11 – 11'	1.629	1.261
14 – 14'	1.860	1.328
15 – 15'	1.638	1.170
16 – 16'	1.865	1.297
*17 – 17'	1.314	1.044
*18 – 18'	1.449	1.136
*19 – 19'	1.501	1.181
*20 – 20'	1.413	1.115
I – I'	1.572	1.198
II – II'	1.561	1.057
III – III'	1.562	1.280

**lower height than 15 m*

The stability coefficients for the static and dynamic loads per profile II - II', which was the most critical before the introduction of rehabilitation measurements, after the application of these measures, are shown in Figures 7 and 8.

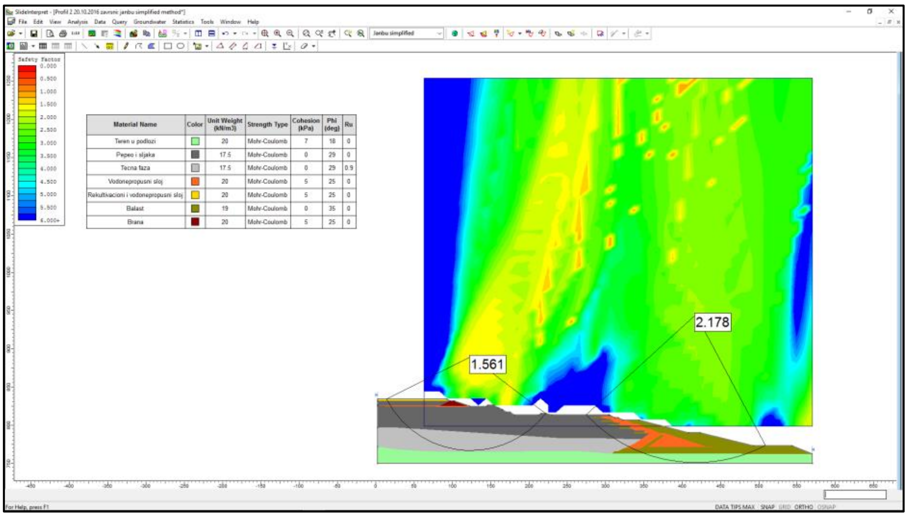

Figure 7 *Static stability coefficient on profile II – II' after application the rehabilitation measures*

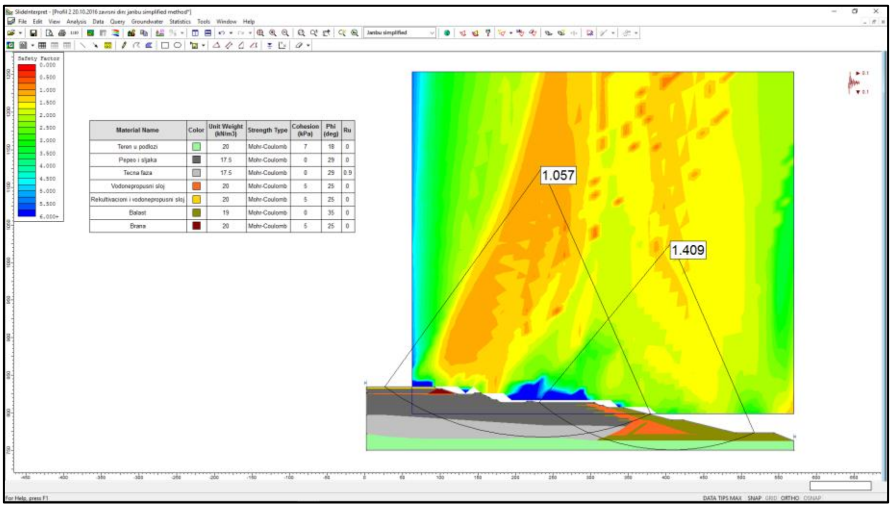

Figure 8 *Dynamic stability coefficient on profile II - II' after application the rehabilitation measures*

CONCLUSION

According to the technical conditions for designing the dams and hydrotechnical dikes - SRPS U.C5.020, for the dams (dikes) over 15 m in height with the constant load occurring in the regular exploitation of the structures for a longer or shorter period of time, the obtained static stability coefficients satisfy the prescribed standard, while in a dynamic sense, an instability occurs according to the prescribed standard.

In parts of the mentioned area where the regulation of the mentioned standard is not satisfied, the actions should be taken to bring this condition to the limits prescribed by the standard. Most of the problems with stability is in the cassette I, where the instability occurs due to a high level of the ash and slag liquid phase. Reduction the level of the liquid phase below the cassette I and by some of the rehabilitation measures, the conditions will be created for increasing the stability coefficient on the critical profile II - II' above the prescribed values.

The predicted rehabilitation measures are:

1. Covering the cassette I with a layer of low-permeable clay, thickness 1 m;
2. Covering the 5^{th} step of the main dam with a clay layer of 1 m;
3. Construction of a new horizontal precipitator with clay and HDPE foil;
4. Closure of the existing precipitator and covering a clay layer of 1m;
5. Construction of drainage wells on the 5^{th} step of the main dam for lowering the water level in the landfill;
6. Upon termination of exploitation of the cassette II, closure of cassette with a clay layer of 1m and 1m of soil for rehabilitation of the cassette.

After application of these measures, the stability coefficients after the overtop to the peak elevation K+832 m are in the values prescribed by the technical conditions for designing the earth dams and hydro-technical dikes - SRPS U.C5.020.

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